EMBRYOLOGY.

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EMBRYOLOGY.

ORIGIN AND DEVELOPMENT OF THE BODY AND ITS ORGANS.

In the preceding parts of this work the anatomy of the body has been described chiefly in the adult or fully-formed condition. In the following section it is proposed to bring together the principal facts which are known regarding the first origin of the human organism from the ovum, and the successive changes of development in the embryo or fœtus* by which it attains its complete form and structure. As, however, the knowledge derived from direct observation of the human ovum is still insufficient for a detailed history of its development, more especially in its earlier stages, it will be necessary to refer frequently to the corresponding phenomena as ascertained to occur in mammals and birds, and even in some other animals lower in the scale. In treating of this subject attention will be mainly given to the morphological view, the development of the textures having already been described in the histological part of this volume.

I. THE OVUM BEFORE EMBRYONIC DEVELOPMENT.

Our primary object being the description of the origin and changes of the organic elements out of which the new being is formed, we shall first take up the history of the ovarian ovum at the time when it is approaching maturity, and is about to leave the ovary, reserving the account of the origin of the ovum itself for a later part, when we shall have to treat of the special development of the reproductive organs. We shall next trace the changes of structure in the ovum which follow upon its separation from the ovary and fecundation, and which result in the formation of its more strictly germinal part, out of which, as an organised basis of formative material, the embryo is subsequently developed.

I. THE OVARIAN OVUM.

The human ovum, like that of mammals generally, is a comparatively small spherical body of about $\frac{1}{125}$th or $\frac{1}{120}$th part of an inch in diameter, and so long as it remains in the ovary, the seat of its formation, is contained in one of the Graafian follicles of that organ. As the time of maturation approaches, while the size of the ovum itself is very little increased, the follicle undergoes great enlargement, so as to attain at last a diameter of one-sixth or one-quarter of an inch or even more. This enlargement is in great part due to the increase of the albuminoid fluid which occupies a large part of the interior; but it is of course also attended with a great multiplication and extension of the cells which constitute the so-called *tunica granulosa* surrounding the interior, and of the substance of the follicular wall itself. The ovum is imbedded in a thickened portion of the *tunica granulosa,* which since the time of Von Baer has received the name of *discus proligerus,* and is thus placed near the inside of the wall of the follicle; and when this most projecting part is fully developed, most frequently at the side next the surface of the ovary. But on this point observers differ, and at an earlier period especially it appears that the position of the ovum may vary greatly, and is not unfrequently on the deeper side of the follicle.

---

* It has been customary to make a distinction between the terms "embryo" and "fœtus" by applying the first to the earlier and the second to the more advanced stages in the development of the new organism; but although such a distinction may be convenient, it is not always maintained by authors, and the terms are sometimes used indifferently.

The small and almost microscopic body which constitutes the human ovum, like that of most mammals, which it closely resembles, possesses a very definite structure, which, as already partly explained in the Histology, is that of an organised animal cell. In this view of its nature, we recognise in it an enclosing cell-membrane or cell-wall, the protoplasmic and other contents, and among these the nucleus and nucleolus; corresponding more or less with parts which have been long familiarly known in the larger ova of birds and some other animals, under the names of yolk membrane, yolk or vitellus, germinal vesicle, and germinal spot.

As in all other animal cells, the main part of the cell substance of the ovum is essentially of the nature of protoplasm, but in the yolk the simple and homogeneous protoplasm is more or less mixed or associated with a different kind of substance, viz., the vitelline granules or corpuscles, which are not immediately or directly connected with the formative processes, but yet serve in a secondary or subsidiary way for the nourishment of the protoplasm and the parts developed out of it. Hence the distinction in most if not in all ova which has been recognised since it was made by Reichert in 1840 (No. 18), between the germinal or formative yolk substance and the nutritive or food yolk. It is mainly on the wide variation in the relative quantity and disposition of these two components of the ovicell that the great differences depend which are observable among the ova of different animals.

Different Forms of Ova.—The human ovum and that of mammals belong to a group of ova in which the proportion of food-yolk is very small, while that of birds, reptiles, and elasmobranch fishes is distinguished by the very large quantity of this material, as well as by the proportionally large size of the whole ovum. In the egg of birds the yolk (which alone is to be compared to the ovarian ovum of mammals) consists in great part of large vitelline corpuscles or spheroidal groups of granules, and the primary seat of embryonic development is limited to the small whitish spot called cicatricula, about $\frac{1}{6}$ of an inch in diameter, which lies close to the pedicle in the ovarian capsule, and in a newly laid egg on the side of the yolk which naturally floats uppermost. The germinal vesicle, which is of considerable size, $\frac{1}{60}$ to $\frac{1}{50}$th of an inch in diameter, lies embedded in the centre of the cicatricula so long as the yolk remains within its ovarian capsule, and it is to this part, composed of comparatively pure protoplasm, that the first changes connected with embryonic development are restricted. Thus the centre of the cicatricula and place of the germinal vesicle have come to be recognised as the upper or germinal pole of the egg, and to be distinguished from the opposite lower side of the yolk which may be termed the antigerminal or nutritive pole. So also it has been customary to distinguish such ova as those of birds by the term *meroblastic,* as indicating that a part only of the yolk is directly or primarily germinal or engaged in embryonic development. In the ovum of mammals, on the other hand, the whole yolk undergoes from the first the formative changes which result in the production of an embryo, and such ova have hence been named *holoblastic*. But though the distinction here mentioned is undoubtedly well founded and important, and the terms applied to the two most contrasting forms are so far appropriate, it appears that the intermediate gradations and varieties in the relative quantity and disposition of the germinal and nutritive portions of the yolk are so numerous, that it is found impossible to make a complete subdivision of the ova of animals according to this character.

But while the mature ovarian ova of birds and mammals appear at first to differ very widely from each other, a comparison of intermediate forms and the observation of their earlier condition shows in a convincing manner that they have essentially a homologous structure, and that notwithstanding the very large size and the apparent complexity of structure in the egg of the bird, both kinds of ova have in common the elementary form of the simple animal cell.

It is obvious that the great difference in size between the avian and the mammalian ovum has reference to the mode of nutrition of the embryo in the progress of its development, as modified in the one case by the complete separation of the egg from the parent body, which necessitates the provision within it of all the nourishment required for the whole duration of incubation; and in the other case by the dependent and attached condition of the ovum and its annexes which enables them to draw a supply of nutriment from the parent during the whole of gestation.

MAMMALIAN OVUM.

The Yolk Substance.—In the mammalian or human ovarian ovum which is approaching maturity, the yolk substance forms a well-defined spherical mass, completely filling the cavity of the containing membrane. The yolk is at no place perfectly clear or homogeneous, but exhibits throughout a certain turbidity from minute granules imbedded in the purer protoplasm. The amount of yolk granules, which varies considerably in different animals, is small in the human ovum, and in general the granules are of smaller size and in less number near the surface of the yolk and in a space immediately surrounding the germinal vesicle. The yolk granules, or yolk corpuscles, as the larger may

Fig. 622.

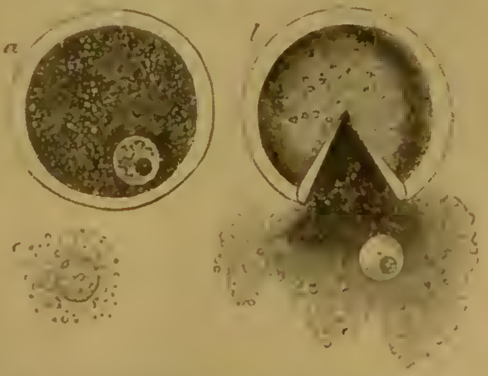


Fig. 622. OVARIAN OVUM OF A MAMMIFER. $\frac{250}{1}$. (A.T.)

a, the entire ovum, viewed under pressure; the granular cells have been removed from the outer surface, the germinal vesicle is seen in the yolk substance within; *b*, the external coat or zona burst by increased pressure, the yolk protoplasm and the germinal vesicle having escaped from within; *c*, germinal vesicle more freed from the yolk substance. In all of them the macula is seen.

be termed, are chiefly spherical in form, and are of the most various sizes, from the minutest molecules up to the diameter of $\frac{1}{1000}$ or $\frac{1}{1500}$th of an inch. They are different in composition from the clearer protoplasm, consisting mainly of protagon with fat and some other ingredients.

Fig. 623.

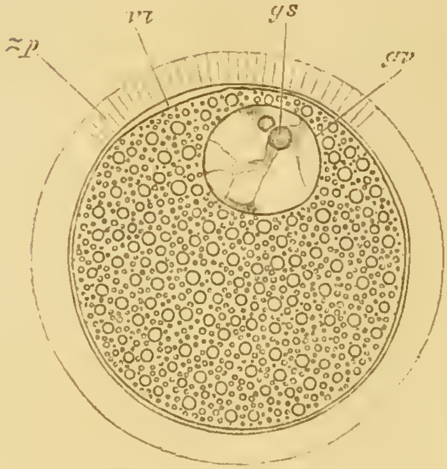


Fig. 623.—Ovum of the cat; highly magnified. Semi-diagrammatic. (E.A.S.)

zp, zona pellucida, showing radiated structure; *vi*, vitellus, round which a delicate membrane was seen; *gv*, germinal vesicle; *gs*, germinal spot.

They are enclosed in the substance of the more homogeneous protoplasm. The latter presents in the living state all the characters of this substance, sometimes exhibiting the finely radiated linear or fibrillar structure which belongs to its growing condition, and possessing the amœboid contractile property which is known to characterise most of its forms.

Germinal Vesicle.—While the protoplasm and vitelline granules constitute the main part of the cell-substance of the ovum, the germinal vesicle is an invariable constituent and forms its nucleus. In the ovum which has not yet arrived at complete maturity this body has a spheroidal shape, and consists of a matrix containing nucleoplasm enclosed in a fine but distinct homogeneous vesicular membrane, and is for the time situated in a clearer part of the yolk protoplasm near the surface on one side which thus becomes the germinal pole. Its size in mammals generally is about a fourth part of the diameter of the ovum, and therefore in the human ovum it may be about $\frac{1}{500}$th of an inch in diameter, being actually smaller but proportionally larger than in birds. The substance of the germinal vesicle corresponds in all respects with the usual contents of growing cell-nuclei, and may therefore be described as nucleoplasm.

Germinal Macula or Spot.—In mammals there is generally one principal nucleolus of a regular spherical or lenticular form, and presenting not unfrequently a well-defined outline. This is the macula germinativa of Rudolf Wagner, now generally recognised as corresponding to the cell-nucleolus. In mammals, however, as in other animals, the macula or nucleolus may be subdivided into several, of which one is usually larger than the rest; and in this one we may perceive an internal division into smaller opaque granules. The nucleolus appears, as in other cells, to consist mainly of a granular modification of the cellular nucleoplasm.

Zona Pellucida.—The most obvious enclosing membrane of the mammal's ovum is that already referred to as the zona pellucida,—a name given to it by Von Baer on account of the appearance which it presents, in a nearly ripe ovum extracted from a Graafian follicle, of a clear broad band lying between the opaque yolk substance within and the granular cells of the proligerous disc which adhere to it externally.

This vesicular envelope of the ovum is of considerable thickness and of great strength, bursting only under strong pressure or by the aid of cutting instruments. Under a moderate magnifying power, when freed from the adherent cells of the proligerous disc, it appears homogeneous; but when subjected to higher magnifyers, such as 500 or 600 diameters, it frequently exhibits a linear radiation through its thickness, which bears some resemblance to the more distinct radiated and porous structure in the egg covering of osseous fishes, insects, and some other animals. And some are of opinion that the pores of the covering of the mammal's ovum are capable of transmitting minute granules or even cells from the exterior into its cavity; but it seems probable that such a condition of the pores is not constant, and that their occasional enlargement, as observed by Lindgren (No. 65) and Von Sehlen may depend upon unnatural circumstances (No. 66).

Fig. 624.

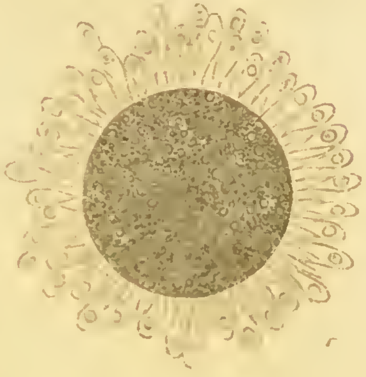


Fig. 624.—Mature ovarian ovum of the guinea-pig (from Bischoff.) $\frac{350}{1}$

The zona pellucida is hidden by the adherent cells of the membrana granulosa, which have assumed a pediculated form next its surface. The finely granular yolk substance fills the cavity of the zona. The germinal vesicle has disappeared.

In 1841 Reichert described a second more delicate membrane as immediately surrounding the yolk substance in the mammal's ovum, and more recently Edw. Van Beneden (No. 57) has affirmed the existence of such a membrane, and adheres to this opinion in the account of his latest researches (No. 63). This membrane he finds to be formed in the mammal's ovum as it approaches maturity, and to remain visible for some time after it has left the ovary. F. M. Balfour (Nos. 32 and 62) is inclined to adopt the same view, while other embryologists still entertain doubts as to its existence.

In 1840 Barry thought he had discovered in the rabbit's ovum a distinct foramen or perforation of the zona pellucida similar to the *micropyle* of fishes, insects, and some other animals, and Pflüger and E. V. Beneden for a time supported this view. But the last observer has from his most recent observations been led to abandon it, and as many other embryologists have sought in vain for this aperture, it may now with certainty be considered as absent from the mammiferous ovum in the more distinct form described by Barry, although occasionally, as before stated, minute pores or radiating canals are seen to pierce the zonal membrane.

The Mammalian ovum was discovered by Von Baer in 1827 (No. 49). The germinal vesicle, which had been made known in Birds by Purkinje in 1825 (No. 48), was first described in the Mammal's ovum by Coste in 1833 (No. 50, i.), having also been independently observed by Thomas W. Jones in 1834 (No. 51, i.). The macula or nucleolus was first pointed out by Rudolph Wagner in 1835 (No. 52, i. & ii.). See the Bibliography, Nos. 47 to 66.

II. MATURATION OF THE OVUM AND SEPARATION FROM THE OVARY.

It was long known that at or near the time of the full maturation of the ovum and its leaving the ovary, both in birds and mammals, the germinal vesicle, which had gradually approached the surface of the ovarian ovum in the later stages of its development, finally disappeared or was lost to view. It was not certain however that this occurred in an animals, nor was it known how the disappearance was to be explained, and whether any part or how much of the substance of the germinal vesicle, as was vaguely conjectured, might have remained to undergo further changes, to combine with the yolk, or to form the basis of an embryonic nucleus. Improved modern methods of histological research have led to the discovery of some of the phenomena of retrogression of the germinal vesicle and the foundation of the germ of a very remarkable kind, of which a short account will be given at this place.

Fig. 625.

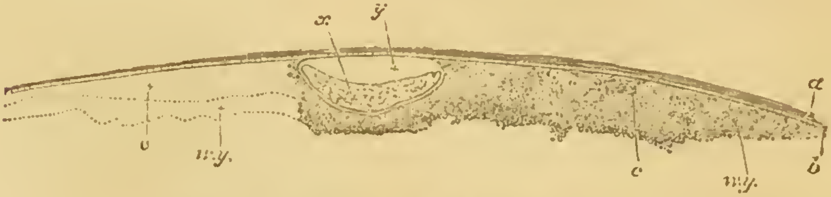


Fig. 625.—VERTICAL SECTION THROUGH THE GERMINAL DISC OF THE RIPE OVARIAN OVUM OF THE FOWL, IN ITS CAPSULE. (From Balfour.)

a, Connective tissue of the ovarian capsule ; *b*, its epithelium, close to which is the vitelline membrane of the ovum ; *c*, granular protoplasm which undergoes segmentation ; *w.y*, white yolk substance ; *x*, substance of the germinal vesicle shrivelled up ; *y*, space left by this shrinking within the membrane of the vesicle.

Exclusion of the Polar Globules, and Formation of the Female Pronucleus.—These phenomena of retrogression in the germinal vesicle are intimately connected with another appearance which since its first discovery by Dumortier in 1837, and further investigation by F. Müller in 1848, has been familiar to embryologists in a very wide range of animals, viz., the formation or extrusion from the yolk at the time of complete maturation of the so-called *polar* or *directing* globules, of which the relation to the germinal vesicle has only recently received a more minute investigation, although various more or less probable suppositions had been from time to time formed as to their nature.

Fig. 626.

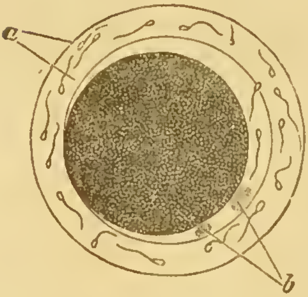


Fig. 626.—OVUM OF THE RABBIT FROM THE FALLOPIAN TUBE, TWELVE HOURS AFTER IMPREGNATION. (From Bischoff.)

In the zona *a*, spermatozoa are seen ; *b*, two hyaline globules or polar bodies within the cavity left by the shrinking of the yolk.

The most precise and satisfactory of the recent observations now referred to have been made chiefly upon the ova of animals comparatively low in the scale, but we are not without evidence that nearly similar phenomena occur also in the higher animals and especially in mammals. We shall first describe shortly the results of observations made by Bütschli, Fol, and Hertwig on the ova of some Echinoderms and Heteropods ; referring the reader to the works quoted at p. 22 of this volume, and to the very clear account of the phenomena given by Balfour (No. 32, vol. i. p. 55, and No. 76).

In the Asterias glacialis, according to Fol, as soon as the ripe ovum is detached from the ovary and placed in sea water, the germinal vesicle, which was previously of a regular spherical shape and presented the nuclear reticulum and all the usual characteristics of such structures, loses its external membrane and its internal reticulum, takes an irregular outline and undefined structure, and becomes to some extent confounded with the vitellus. The germinal macula also gradually disappears. Between the remains of the germinal vesicle and the surface of the yolk there now appears a nuclear spindle or double cone terminating externally in a star-like arrangement of the protoplasm. Soon afterwards another star appears and the nuclear spindle lies horizontally between the two stars. Oscar Hertwig observed phenomena very nearly similar in another Echinoderm (Asteracanthion), but it was not determined by either of these sets of observations, what share, and whether any, the macula took in the changes which occurred; but further observations by Fol on one of the Heteropodes (Pterotrachæa) made it certain that the metamorphosis of the germinal vesicle results in the formation of a nuclear spindle with the two stars lying near the surface of the ovum, and that these phenomena, as was well known also in other animals, are quite independent of fecundation.

Fig. 627.

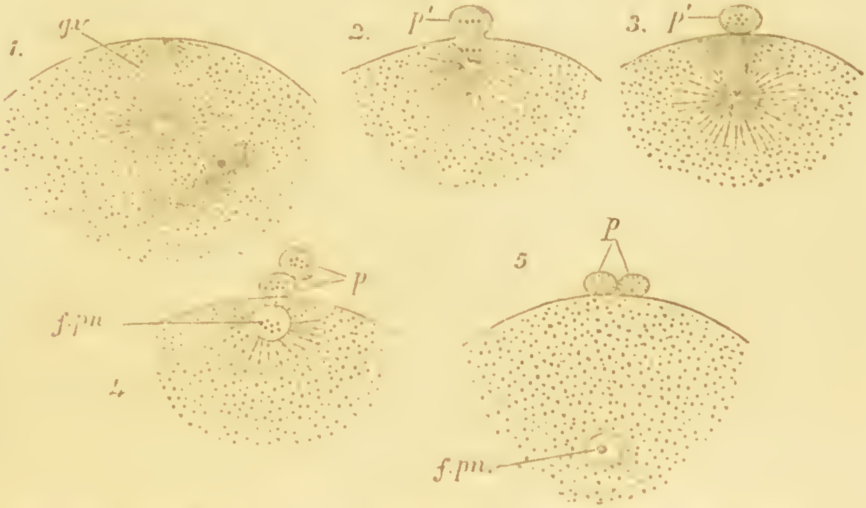


Fig. 627.—Stages in the formation of the polar globules in the ovum of a star-fish (from Hertwig.)

gv, germinal vesicle transformed into a spindle-shaped system of fibres; *p'*, the first polar globule becoming extruded from the surface of the ovum; *p*, polar globules completely extruded; *f.pn*, female pronucleus.

The next change consists in the spindle assuming a vertical instead of a horizontal position, and in the subsequent projection of one end or star in a protoplasmic prominence or knob from the surface of the yolk. By a constriction which follows in the outer part of this prominence, a small spherical mass of clear protoplasm constituting the *first polar body or globule* is separated and takes its place close to the original site of the germinal vesicle in a space now formed by the shrinking of the yolk between the surface of that body and the enclosing membrane.

The process of nuclear division being repeated in the spindle-shaped body, another polar globule is separated in a manner similar to the first;

and the irregular remains of the germinal vesicle within the yolk gradually assume the more regular spherical form and clear appearance of a nucleus, which sinking more deeply into the yolk now constitutes the *female pronucleus*.

It is probable that similar phenomena occur in all animals. They have been observed more or less completely in Petromyzon, the Sturgeon, Osseous Fishes (Trout), Amphibia, and among Mammals in the Rabbit and Bat. The following are the principal results of the observations of Edw. Van Beneden on the latter two animals.

The germinal vesicle of the ovum which approaches maturation flattens out, and rising to the surface fuses with the superficial part of the yolk protoplasm in a lenticular form. The germinal spot proceeding to the surface of this becomes discoid, while the membrane of the germinal vesicle vanishes or unites with the disc. The plasma of the nucleus collects into a nucleoplasmic mass, and along with the nuclear disc remains for a short time within the ovum. Soon afterwards, however, a polar body is found outside the yolk, composed of two parts, of which one stains deeply in the same manner as the discoid part of the nucleus, while the other resembles the nucleoplasmic substance in not staining. Van Beneden looks upon these parts of the polar body as the ejected products of the germinal vesicle; but Balfour considers it more probable that a part of the germinal vesicle remains in the ovum to form the female pronucleus.

The shrinking of the yolk coincides with the expulsion of the first polar body which usually takes place before the rupture of the follicle; the second polar globule is more frequently expelled after the ovum has entered the tube, and along with its appearance there is a further shrinking of the yolk; but all these phenomena are quite independent of fecundation or any influence of the male sperm.

Separation from the Ovary.—It is now well ascertained that the maturation and the discharge of the ovarian ova and the accompanying changes to which the Graafian follicles are subject recur periodically during the breeding period,—in the human female at every successive menstrual term, and in animals at the times of heat,—and that these changes take place independently of the influence of the male or of impregnation (Bischoff, No. 67).

In animals, such as the sheep or dog, when the state of heat has lasted some days, and in the human female at or near the time of the menstrual flow, the ovum is discharged by the rupture of the thinner and most projecting part of the Graafian follicle. The aperture takes place at a spot, the macula or stigma, which is non-vascular, is small and with irregular or ragged edges, and its formation by a solution of continuity of the tissue is preceded by increased vascularity in the neighbourhood. The ovum in escaping remains imbedded in the cells of the discus proligerus which adhere closely to it, and it is probably accompanied by parts of the tunica granulosa and some of the fluid of the follicle. These are pressed out of the follicle in part by the elastic reaction of the dilated theca, and in part by the increasing development of new cellular elements in the interior of the follicle.

By a mechanism which it does not belong to our present view to describe, the ovum with its accompaniments is received into the wide fimbriated mouth of the Fallopian tube, and descending in that canal, if not fecundated, gradually disappears or is lost: but if subjected to the fertilizing influence of the semen, begins to undergo the changes of development which lead to the formation of an embryo.

The Graafian follicle, as already indicated, comes soon to be occupied by the body named from its yellow colour *corpus luteum*, and it is important to observe that this takes place in all cases of the rupture of a follicle, whether or not it has been followed by impregnation. The changes involved in the formation of this body and its structure have been already described at p. 336 of this volume.

III. FECUNDATION OF THE OVUM.

The process of fecundation, which will be considered here only in its relation to the formation of the germ, consists, in its most general acceptation, essentially in the union of the male and female generative elements. For the history of the male generative element we refer the reader to the account given at p. 698 of this volume.

Introduction of the Spermatozoa into the Ovum.—The fact of the actual entrance of spermatozoa within the zona or covering of the mammiferous ovum was first observed by Martin Barry in 1843, and although his statement was received with considerable hesitation by his contemporaries, it has since been repeatedly confirmed by the minute and careful investigation of many observers.

In certain animals the spermatozoa have been seen to enter the cavity of the ovum by an obvious micropyle aperture, as first observed by Ransom in fishes (No. 72), and by Meissner and Leuckart in insects; but in mammals and other animals in which no such aperture exists, it is not yet clearly understood in what manner the spermatozoa make their way through the consistent membrane of the ovum.

Changes in the Ovum and Spermatozoa giving rise to a Male Pronucleus.—In mammalia, although the spermatozoa are ascertained to pass in numbers through the zona, they have not been observed in any case to penetrate or combine with the substance of the yolk. It is extremely probable that such combination does take place, but we only know of this occurrence by observations made on the lower animals, which, however, throw so much light on the whole process of fecundation that it is proper to give an account of them in this place.

Fig. 628.

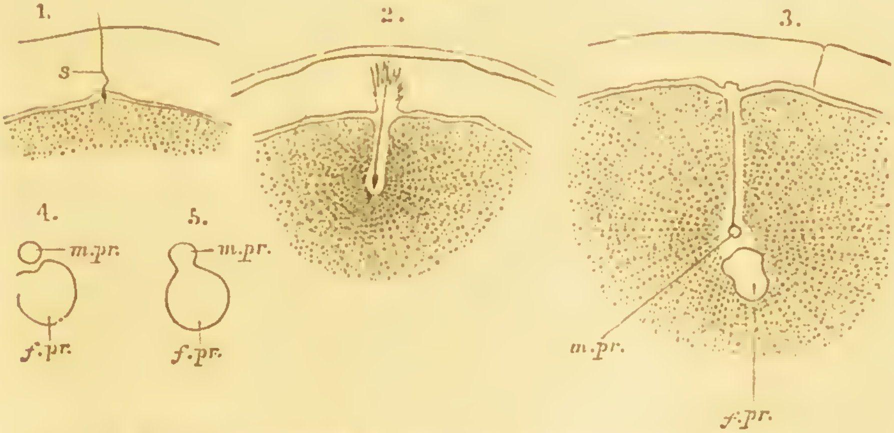


Fig. 628.—Fertilization of the Ovum of an Echinoderm (Selenka.)

s, spermatozoon; *m.pr*, male pronucleus; *f.pr*, female pronucleus.

1. Accession of a spermatozoon to the periphery of the vitellus; 2. Its penetration, and the radial disposition of the vitelline granules; 3. Transformation of the head of the spermatozoon into the male pronucleus; 4, 5. Blending of the male and female pronuclei.

In this account we shall follow mainly as before the statements of Fol and Hertwig, together with some others as described in Balfour's very clear account of this subject.

In the Asterias glacialis, the female pronucleus, formed simultaneously with the ejection of the polar globules and independently of fecundation, having retired towards the centre of the ovum, a number of spermatozoa penetrate with active motions the mucilaginous egg covering, with their heads directed inwards and their tail filaments extending radially outwards.

In Selenka's account of these phenomena as illustrated by the accompanying figures a clear canal-like space remains in the track of the spermatozoon.

One of the spermatozoa more advanced than the rest comes now to be surrounded and ultimately combined with a prominent part of the yolk substance, and, the tail remaining motionless and subsequently disappearing, the head, or it may be some other part of the spermatozoon, is now gathered together into the form of a nucleus, and, sinking to some depth into the substance of the yolk, becomes surrounded with the radiated lines known to belong to such structures. It is now, in fact, converted into the *male pronucleus*.

Fusion of the Male and Female Pronuclei, and Production of the First Segmentation Sphere.—The male pronucleus gradually approaches the site of the female pronucleus; and as soon as it comes in contact with it, the latter, which was previously motionless, assumes a new activity, and the two pronuclei, impelled perhaps by the amoeboid movements of the yolk protoplasm which accompany the change, finally unite or are fused into one.

The result of this union is the formation of the first *embryonic* or *segmentation sphere*, or *Blastosphere*, which may be regarded as a nucleated protoplasmic cell, containing the products of the male and female generative nuclei, or some portion of them, combined with the yolk protoplasm of the ovum.

In mammalia Van Beneden has shown that the first segmentation nucleus owes its origin to the fusion of two previously existing nuclei which could be no others than the male and female pronuclei. In Petromyzon, Calberla, Kupffer and Benecke have demonstrated that a single spermatozoon at first enters the ovum, and the researches of Bambeke and Hertwig make it extremely probable that in Amphibia similar phenomena attend the maturation and fecundation of the ovum, while Oscar Hertwig has traced in Echinus lividus the entrance of the spermatozoon into the ovum and its transformation into the male pronucleus. Precisely similar phenomena have been ascertained by Salensky to occur in the sturgeon; so that there is good reason to believe them to be universal among bisexual animals. (See Balfour, No. 32 and No. 76.)

Differences in the details of these phenomena may occur in different animals, more especially according as impregnation may take place before or after the separation of the polar globules. In the former case, as in Echinus, the male pronucleus is comparatively small, but in the latter case, as in Hirudinea, Mollusca, and Nematodes, in which the polar globules are not fully separated till after impregnation has taken place, the male pronucleus becomes as large as the female.

It appears further that while one spermatozoon is probably sufficient for fecundation in most instances, a greater number may occasionally penetrate the yolk substance, and Fol states that when this occurs each spermatozoon has a distinct pronucleus formed round it, and that several of these may combine with the female pronucleus.

Ever since the similar origin of the generative elements of the two sexes has been ascertained, it has been customary to regard fecundation as consisting essentially in the union of the male and female generative cells: but we can now attach a much more definite idea to this view when we know that the act of fecundation consists in the fusion of a male and female pronucleus, of which one has sprung from the remains of a primitive ovicell, and the other is the product of a primitive sperm cell, and that both of these have had their origin in similar elementary structures of the parent while in the embryo stage of its existence. (Balfour, No. 32. Balbiani, No. 64, and Bibliogr. Nos. 67 to 76.)

IV. SEGMENTATION OF THE FECUNDATED OVUM, AND FORMATION OF THE BLASTODERM.

It is a general fact among bisexual animals that within a very short time after the fertilization of the ovum has been effected by the combination of the sexual elements, the blastosphere or nucleated mass of productive protoplasm which results from the act of union proceeds to undergo a process of division and multiplication after the manner of cell cleavage, and by the ordinal repetition of that process for a considerable number of times there is eventually produced a collection of *blastomeres* or nucleated cells, out of which the further development of the embryo subsequently takes place. To this mass of cells capable of embryonic development the name of protembryo or primitive embryo might be applied, but it is the same which has been called *germinal membrane* or *blastoderm* in the higher animals, because of the flattened or laminar form which the collection of its cells generally presents.

To this process of cell division and multiplication in the fecundated ovum the names of yolk cleavage, or more strictly germ-segmentation are applied. Though common to all the metazoa it presents many and great variations in the different classes of animals, and even among some allied families. Here we must confine our attention mainly to those forms in which the phenomena tend to illustrate the process as it occurs in Mammalia.

Different Forms of Segmentation among Animals.—The more important of these varieties are obviously related to the difference in the proportion of the nutritive and germinal material in the holoblastic, meroblastic, and intermediate forms of ova. In the case of mammals, the whole mass of the yolk is subject to this change, or is immediately involved in the process of cell division, while in the meroblastic ovum of the bird the first cleavage and consequent formation of a blastoderm is limited to that small portion of the yolk which is termed the germinal disc or cicatricula, and which is alone the seat of the earliest phenomena of development.

This difference constitutes the distinction between *total* and *partial* segmentation, of which we shall have to consider more fully the phenomena, and with regard to which it is only necessary to say further at this place that there is a close inverse relation between the extent of the segmenting process and the quantity of the nutritive yolk substance which is associated with the purer protoplasm of the ovum; and thus through the amphibia and other animals, besides variations of other kinds, all possible gradations are to be found in the proportion of the substance of the ovum which is primarily involved in the cell-forming process resulting from segmentation.

The intermediate form of segmentation which occurs in the Amphibia, as in the frog or newt, is so instructive that it will be proper to introduce a short description of it at this place before proceeding with that of mammals and birds.

Complete and Unequal Segmentation in Amphibia.—In the batrachian ovum the segmentation may be regarded as total or complete in so far that it extends from the first throughout the whole mass of the yolk, but it may be considered as *unequal* in this respect, that there is in some sort a concentration of the process towards the germinal pole, where the cells resulting from the yolk cleavage are smaller and more numerous, while they become gradually larger and less distinctly separated towards the opposite or nutritive pole—a difference which is manifestly related to the purer condition of the egg protoplasm in the neighbourhood of the first, which was the original seat of the germinal vesicle, and the larger quantity of nutritive yolk accumulated at the lower or antigerminal pole. The accompanying diagram copied from Ecker gives a sufficiently clear view of the successive steps of the process; 1 representing the undivided condition, 2 the first vertical cleft which divides the whole yolk into two, 4 indicates the stage at which by a second vertical cleft the yolk is now divided into four segments. In these two first stages the vertical clefts proceed downwards from the upper or germinal pole, where they cross each other at right angles, to the lower or nutritive pole. In the next stage, however, marked 8, in which that number of segments have appeared, the new cleft is horizontal and parallel to the equator of the sphere, but at some distance above it. This again is succeeded by radial or meridional clefts which, proceeding gradually from the germinal pole, divide first the upper and later the lower segments, so as to produce first twelve and later sixteen segments, as seen in the outline numbered 16. Two equatorial clefts follow, which have the effect of dividing both the upper and lower meridional segments, so as to produce first 24 and subsequently 32 segments; and by a succession of similar alternating vertical and horizontal clefts a greater and greater multiplication takes place, but in such a manner as to give rise to more numerous and smaller and closer cells in the upper germinal and deeply coloured part and fewer and larger and looser cells below.

Fig. 629.

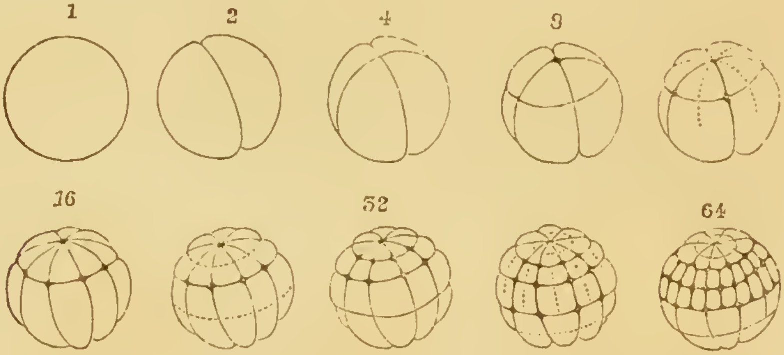


Fig. 629.—Unequal segmentation in the egg of the frog (from Balfour after Ecker.)

Ten stages are represented; the numbers over certain figures indicate the number of segments at each of these stages; in the intervening figures the fissures are in progress of formation.

Up to a certain point the progression is regular, but when the number of segments has become considerable the regularity is no longer perceptible. A cavity at the same time appears, the *segmentation cavity*, which lies between the smaller cells of the upper and the larger cells of the lower division; and these two sets of cells respectively correspond to the upper and lower layers of the blastoderm of higher animals. In the Amphibia then the segmentation, though complete, is from the first unequal. (See No. 26, Tab. 23, Explanation.)

Complete and Equal Segmentation of Amphioxus and Petromyzon.—Segmentation which is at once complete and equal occurs in many of the invertebrate animals, but among the vertebrates or animals allied to them the only examples are those of Amphioxus and Petromyzon. In the case of Amphioxus after the successive reduplication of the yolk-spheres has proceeded to such an extent as to divide the whole into smaller uniform nucleated cells, these cells are found to have arranged themselves as a layer on the surface, while the interior is occupied by fluid, constituting thus a cellular vesicle with a segmentation cavity within ; and the first change which succeeds to this stage consists in the doubling in or invagination of one side of the cellular wall so as to give rise to a secondary cavity communicating with the exterior, while the two sides approach one another so as gradually to narrow and at last obliterate the original cavity which lay between them. The part which remains outside forms the external layer or ectoderm, and that which is doubled in is the internal layer or entoderm. The protembryo or blastoderm thus assumes the form of the bilaminar *gastrula* of Haeckel, communicating with the exterior by the now narrowed aperture called blastopore, and representing in fact the simplest form of an alimentary cavity.

Complete Segmentation in Mammals.—The Mammals come next to the Amphioxus in the completeness and regularity of the segmentation, but they differ from it both in the early distinction of the upper and lower blastodermic cells and in the absence of any obvious invagination of the vesicular blastoderm.

The segmentation of the mammiferous ovum had been seen by Martin Barry, but its general features were first clearly demonstrated by the important researches of Bischoff. In more recent times much light has been thrown upon the nature of this process by the interesting researches of Edwd. Van Beneden (No. 74) and others. From the observations of Van Beneden it appears that in the ovum of the rabbit within one or two hours after the union of the male and female pronuclei the process of division of the nucleus and the primary segment sphere commences.

Fig. 630.

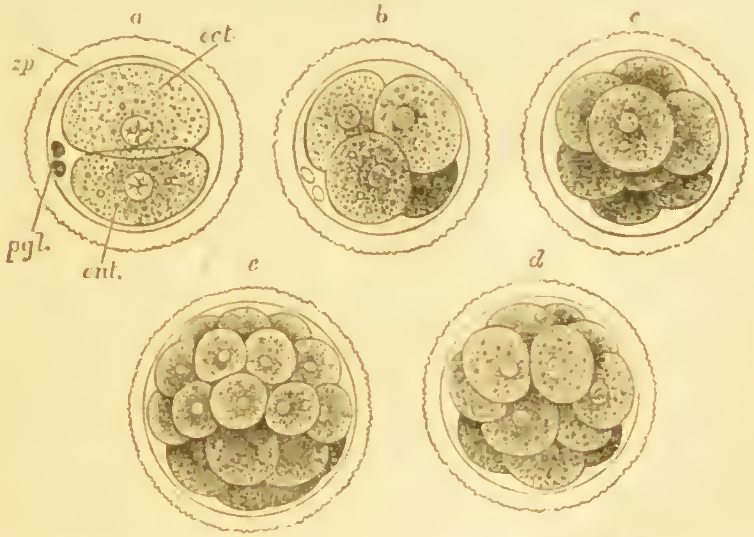


Fig. 630.—First stages of segmentation of a mammalian ovum : semi-diagrammatic. (Drawn by A. T. after Edwd. v. Beneden's description.)

z.p, zona pellucida ; *p.gl*, polar globules ; *ect*, ectomere ; *ent*, entomere ; *a*, division into two blastomeres : *b*, stage of four blastomeres ; *c*, eight blastomeres, the ectomeres partially enclosing the entomeres ; *d.e*, succeeding stages of segmentation showing the more rapid division of the ectomeres and the enclosure of the entomeres by them.

This, as well as all the subsequent divisions which occur, is accompanied by the usual phenomena of spindle modification of the nucleus and radial striation of the surrounding yolk protoplasm. The whole process of segmentation is accomplished in the rabbit within from 70 to 75 hours after fecundation, by which time the ova have passed through the Fallopian tubes and are entering the cavity of the uterus.

The principal phenomena as described by Van Beneden are as follows. First a complete division of the whole yolk into two spheroidal or ovoid masses takes place, the cleft seeming to depart from the place previously occupied by the polar or directing bodies. Each of these spheroids is next divided in a similar manner with the first into two, so that four result, and in a third stage the division of the four spheres brings the number up to eight. It is to be remarked however that the size of the two spheres resulting from the first cleavage is not equal, but the one which we shall call the upper is the largest, and it is also somewhat differently affected by reagents from the lower one; and Van Beneden has suggested the view that this difference is already an indication of a distinction between the cells of the upper and lower layers of the blastoderm (Nos. 74 and 75).

Fig. 631.

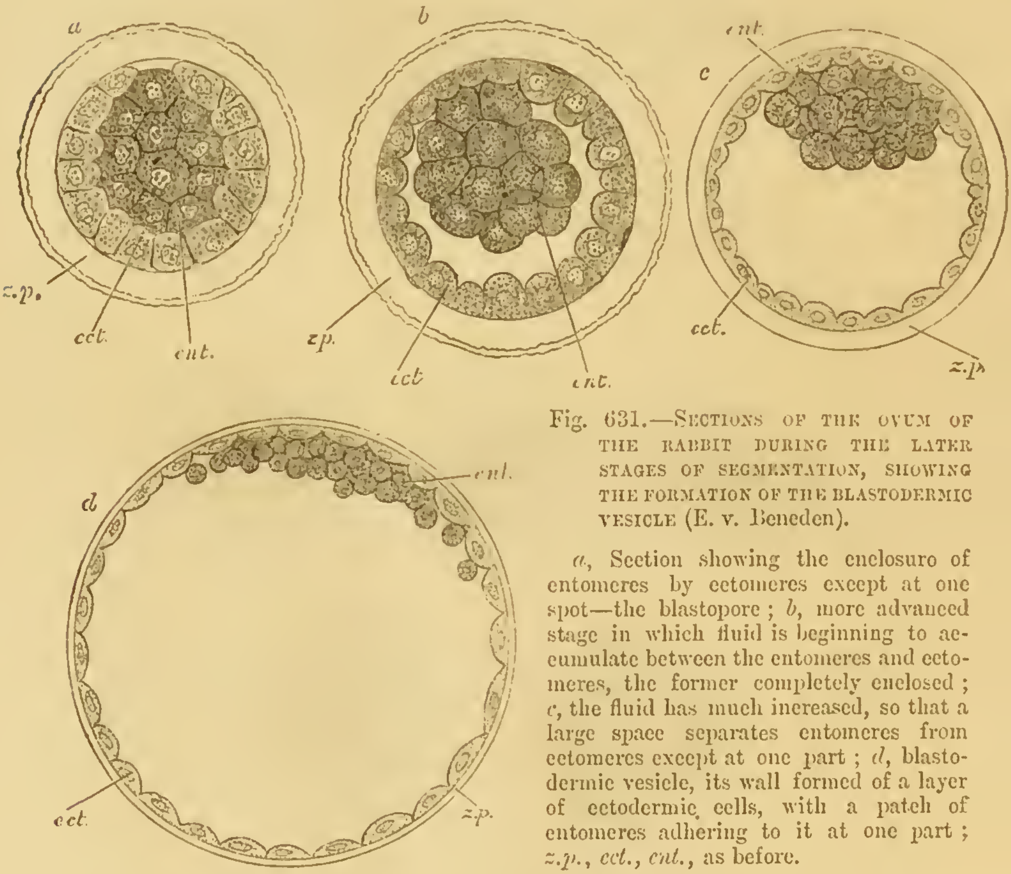


Fig. 631.—Sections of the ovum of the rabbit during the later stages of segmentation, showing the formation of the blastodermic vesicle (E. v. Beneden).

a, Section showing the enclosure of entomeres by ectomeres except at one spot—the blastopore; *b*, more advanced stage in which fluid is beginning to accumulate between the entomeres and ectomeres, the former completely enclosed; *c*, the fluid has much increased, so that a large space separates entomeres from ectomeres except at one part; *d*, blastodermic vesicle, its wall formed of a layer of ectodermic cells, with a patch of entomeres adhering to it at one part; *z.p.*, *ect.*, *ent.*, as before.

When the division has reached the third stage and eight spheres are formed, these are found to have arranged themselves in such a manner that the four lower cells become more closely gathered together by one of them taking a central position with reference to the rest, and the four upper cells at the same time show a tendency to surround and enclose the lower, which at a later period their successors do more completely.

A difference in the rate of division of the upper and lower group of spheres now becomes apparent, that of the upper being somewhat in advance of the lower; and thus in the fourth stage, while the cells of the lower group remain only four in number, the upper have divided and amount to eight. The division of the lower group then brings their number to eight and the whole yolk consists of sixteen spheres.

There is now found also to be a change in the relative size of the upper and lower groups of spheres, the latter having now become the larger and fewer, and also the more opaque and granular in their aspect.

The upper spheres at the same time show more and more tendency to spread over the surface of the lower group which are gathered together in a ball, and thus to surround and enclose them. This enclosure, however, is not complete till the tenth stage, when the whole number of spheres, or cells as they may now be called, is 96, of which 64 are those of the surface, and 32 occupy the interior.

There is a time however during which the external layer of cells, though covering the mass of inner ones, does not completely close them in, but leaves one or more of them visible by an aperture which has been compared by Van Beneden, but according to some on insufficient grounds, to the blastopore or aperture of invagination in the lower animals. This aperture is soon effaced by the union of the external cells over it, and in this stage, which may be regarded as the completion of the segmentation, the ovum is covered externally by an entire layer of nucleated and somewhat prismatic cells, while the interior is occupied by a solid mass of cells of a different character. Thus the whole segmented ovum, which is still only slightly increased in size, is converted into a hollow cellular sphere to which at a later period the name of *blastodermic vesicle* is given.

Partial Segmentation.—The process of segmentation as it occurs in mesoblastic ova contrasts widely in its more apparent phenomena with that previously described, and yet, considered as one of protoplasmic cell-division, and

Fig. 632.

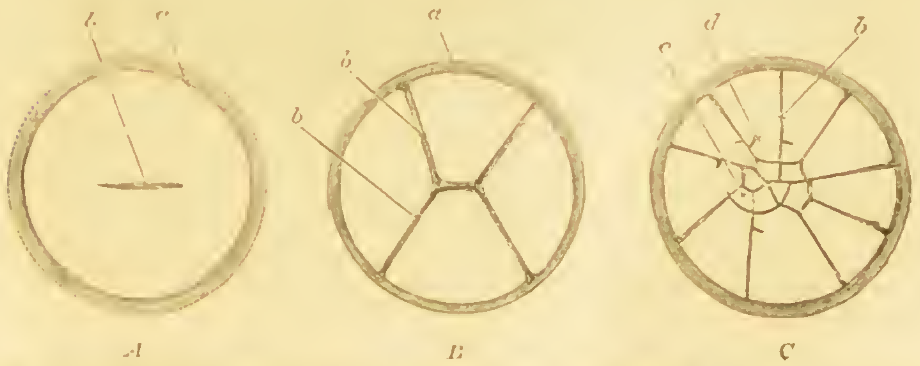


Fig. 632.—SURFACE VIEWS OF THREE EARLY STAGES OF SEGMENTATION IN THE FOWL'S EGG. (From Balfour after Coste).

A, stage of the Primary furrow; B, first Radial furrows; C, other Radial furrows with the first circular; *a*, edge of the germinal disc; *b*, primary and vertical furrows; *c*, smaller central, and *d*, larger peripheral segments.

viewed in the light of the relations of its germinal and nutritive yolk substance to each other in the ovum, the phenomena may be regarded as fundamentally similar. In the egg of the bird, as in the common fowl, the primary segmentation of the germ is limited to the cicatricula or germinal disc, and this process is accomplished during the descent of the yolk or ovarian ovum through the oviduct, and particularly in its lower part, while at the same time the egg is being enclosed in its accessory constituents of albumen, membrane, and shell derived from secretion previous to its being laid. This descent usually occupies in the common fowl from 16 to 24 hours or not much longer period, and the process of segmentation is therefore a comparatively rapid one.

Fig. 633.

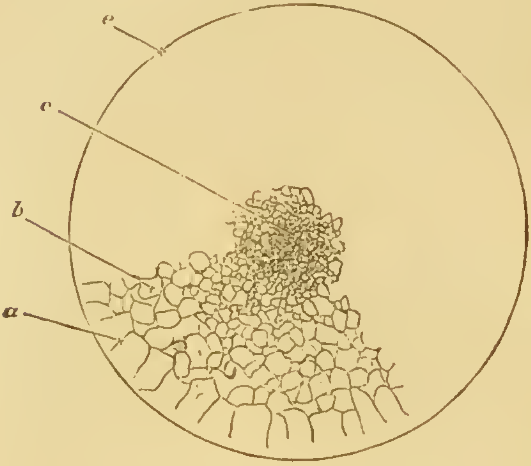


Fig. 633.—SURFACE VIEW OF THE GERMINAL DISC OF THE FOWL'S EGG IN A LATER STAGE OF SEGMENTATION (from Balfour.)

c, small central segmentation spheres; *b*, larger segments outside these; *a*, large, imperfectly circumscribed, marginal segments; *e*, margin of the germinal disc.

The more obvious phenomena attending this process, as observed by Coste (No. 22, iii.) and Kölliker (No. 28 i. p. 70), consist in the occurrence, first of a groove or cleft across the cicatricula in a determinate direction, which appears to be at right angles to the long axis of the whole egg. This is soon followed by another groove, which crosses the first nearly at right angles or intersects it at opposite sides in two separate places. In a third stage the four segments of the germinal disc which were separated by the two first grooves, are again divided by new grooves, each of which, like the first, has a radial disposition, so that eight segments now result. But in a fourth stage the segmenting groove takes a circular or concentric direction, and is such as to cut off a small portion at the upper angle of each of the eight radial segments close to the centre. Sixteen

Fig. 634.

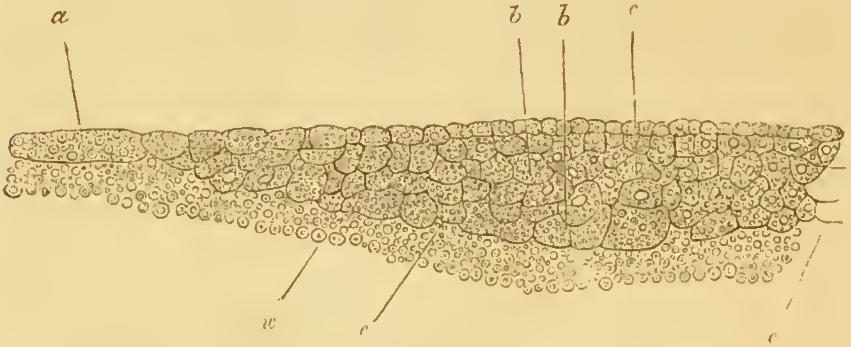


Fig. 634.—VERTICAL SECTION THROUGH MORE THAN A HALF OF THE GERMINAL DISC OF A FOWL IN THE LATER STAGES OF SEGMENTATION (from Balfour.)

c, indicates the middle of the germinal disc; *a*, one of the larger peripheral segments; *b*, larger cells in the deeper part of the blastoderm; *c*, edge of the blastoderm adjoining the white yolk (*w*); most of the cells contain nuclei.

segments are thus formed, and subsequently, by a less regular alternating succession of radial and concentric division the whole disc comes to be divided into smaller portions, within each of which, as appears in the end, a nucleus is formed, and which therefore have the value of true protoplasmic cells. They are in fact the precursors of the formative cells of the blastoderm. It appears further that the cells which thus result from the segmenting process are arranged in two layers, an upper consisting mainly of one range of cells which are clearer and with more defined outlines, and a lower set of cells, which are somewhat larger, more opaque and granular in their aspect and more loosely and irregularly disposed. These layers are separated from the yolk below by a cavity which may be called the segmentation cavity, and they correspond with the primitive layers of the blastoderm.

The nature of the meroblastic form of segmentation now described was first clearly understood from the observations of Kölliker on Cephalopoda in 1844; and the phenomena have since been investigated in reptiles, cartilaginous fishes, and other animals.

In the Teleostei or osseous fishes the segmentation is also partial, but with a nearer approach to the unequal cleavage of the Amphibia.

II. DEVELOPMENT OF THE OVUM IN GENERAL.

I. THE BLASTODERM.

From the preceding account of the segmentation of the ovum it appears that in the amniotic vertebrates the general result of that process is the formation of a flattened or membranous plate or layer of organised cells; and the further observation of the progress of development of the ovum shows that the whole of the genetic changes to which the parts of the future embryo owe their origin take place within, or in close connection with the cellular elements of this plate or membrane. It is essentially therefore the germinal part of the egg, and in the discoid form which it presents in birds was appropriately named by Pander *germinal membrane* (Keimhaut) or Blastoderma, and this name is equally applied to the vesicular form which it presents in mammals and some other animals.

In the sauropsida, and to some extent also in the mammalia, the blastoderm, on the completion of the primary segmentation, does not consist of one layer of cells only, but shows a tendency to division into two layers or two sets of cells, of which the external are generally the more advanced in their state of development. From their relative position these layers may be distinguished as the upper and lower, or outer and inner, primary layers of the blastoderm. Between these two layers, as they become more differentiated, at a subsequent but still very early stage of blastodermic development a third or middle layer makes its appearance, producing thus a trilaminar structure. As the result of all modern embryological research has shown that the first origin and formation of the several systems, organs, and textures of the embryo stand in definite relations to the several layers before mentioned or their derivatives, it will be apparent that the history of embryonic development, more especially in its earlier stages, is in a great measure the narrative of the organogenetic changes occurring in the upper, middle, and lower layers or cellular strata of the blastoderm.

1. **Preliminary Notice of some of the Fundamental Phenomena of Development.**—Before proceeding to consider the somewhat intricate and still imperfectly understood subject of the nature and origin of the blastodermic layers, and their relation to the phenomena of development, it may assist in some degree the comprehension of what is to

follow if we state here as briefly as possible the nature of the earliest steps in the development of the ovum and first appearance of the rudiments of the embryo. In this statement reference will be made chiefly to the phenomena as they occur in the bird's egg, while at the same time it may be mentioned that they are essentially the same in the other Amniota.

Under the influence of the heat of incubation in the fowl's egg, the germinal disc expands at its periphery and as a whole; the outer part, becoming thicker by the accumulation of formative elements derived from the yolk, constitutes the opaque area, and the central part, remaining much thinner, forms the transparent area. The upper layer of the blastoderm extends over the whole of this disc; the lower layer in its primary condition reaches only as far as the inner margin of the opaque area, becoming there continuous with the formative substance of the yolk in the thickened part which is named the *germinal wall.* After a few hours of incubation the transparent area, from being at first nearly circular, becomes oval and then pyriform; and on that side of the oval which afterwards becomes the narrow end of the pyriform space, and therefore near the margin, a sickle-shaped opacity appears (Kupffer, No. 113), which is gradually prolonged into the middle of the area and even beyond it, and as the marginal widening contracts, the whole takes the appearance of a strap-like thickening of nearly uniform diameter throughout. This is the *primitive streak* or trace, which is the first indication of the lineaments of the future embryo. A groove very soon appears in the upper surface of the streak, the *primitive groove,* in which we shall afterwards have to notice certain depressions or perforations of the blastoderm which are of great embryological interest. About the sixteenth hour there is formed in the wider forepart of the transparent area a considerable thickening of the upper layer, which is soon divided by a median

Fig. 635.

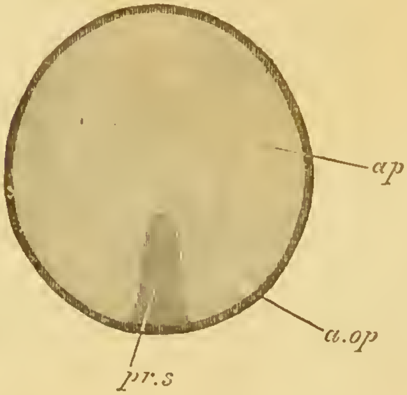


Fig. 636.

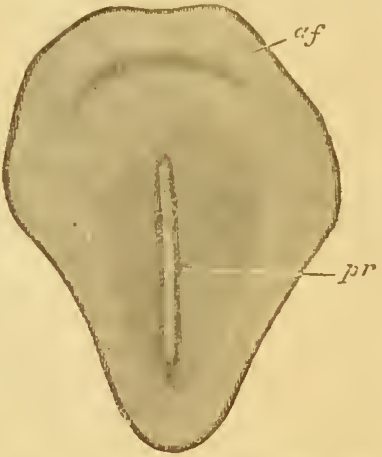


Fig. 635.—Transparent area of the blastoderm of a chick at a very early period, showing the commencement of the primitive streak. (From Balfour.)

pr.s, primitive streak; *a.p*, area pellucida; *a.op*, area opaca.

Fig. 636.—Pyriform transparent area of the chick's blastoderm with the primitive groove. (From Balfour.)

pr, primitive streak and groove; *af*, amniotic fold commencing; the darker shading round the primitive streak indicates the extension of mesoblast.

groove into two ridges, extending backwards so as to enclose partially the front of the primitive streak; they unite or run into one at the fore-part. These ridges and the thickened plates within them are the *dorsal ridges* and *medullary plates* which form the commencement of the brain and spinal marrow or cerebro-spinal axis of the embryo. It will afterwards be shown that the primitive streak and groove are comparatively evanescent and unimportant structures as regards the organs of the future embryo.

The dorsal ridges and medullary plates, continuing to grow steadily, extend themselves from before backwards, so as to encroach more and more upon the primitive streak, which they, along with the mesoblastic columns on either side of them, partly extrude and partly enclose: and the ridges, rising and approaching one another, unite together along the dorsal line, first at a limited space and then more completely till at last they form a closed medullary tube, wider anteriorly in its cephalic part, the whole thus giving rise to the primitive form of the brain and spinal marrow.

Fig. 637.

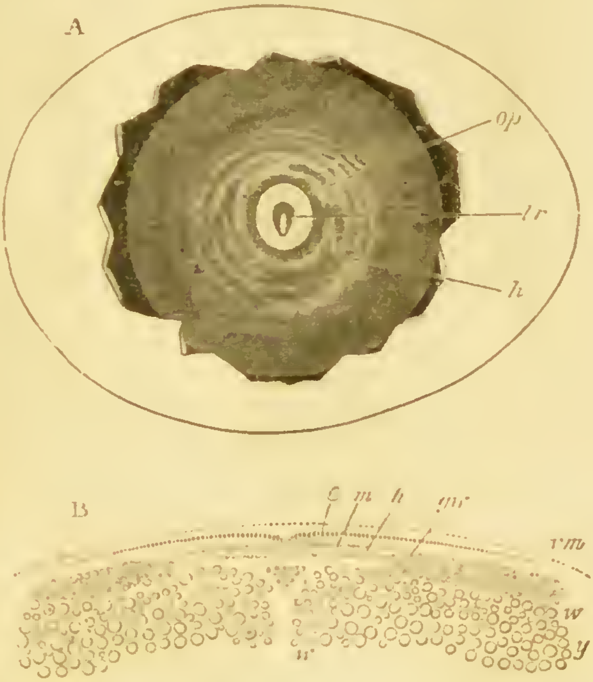


Fig. 637. — Surface view and diagrammatic section showing the relation of the primitive streak and blastoderm to the yolk in a fowl's egg after twelve hours of Incubation. (A. T.)

A, surface view, natural size; *op*, opaque area; *tr*, transparent area, pyriform, and showing the primitive streak in its narrower portion; *h*, haloes of the yolk surrounding the germinal disc; B, section across the disc, and a part of the yolk in the region of the primitive streak, magnified about ten diameters; *vm*, vitelline membrane indicated by a dotted line; *c*, the epiblast in the region of the primitive streak, showing the depression in the middle of the upper surface formed by the primitive groove; *m*, the mesoblast beginning to be formed, and spreading outwards from the epiblast at the primitive streak; *h*, the hypoblast, extending across below and passing at the sides into the germinal wall of the yolk, *gw*; *w*, the white; and *y*, the yellow or granular yolk substance.

Below the medullary tube there is formed about the same time the cellular column named *chorda dorsalis* or notochord, which occupies the place of the centres of the future bodies of the vertebræ and basis of the cranium, and by a somewhat later process the rudiments of the vertebræ themselves in their centra or bodies, which enclose the notochord, and their neural arches which surround the medullary canal, together with the muscular plates, which are the source of the voluntary muscles, come to be developed from the middle layer.

The formation of blood-vessels and blood and the simultaneous development of the heart follow in another part of this layer, and in a somewhat later stage there take place the inflection and other changes of the whole blastodermic layers which mould the body of the embryo into a semblance of its later form, give the distinction of head, trunk, and limbs, and lay the foundation of the alimentary canal, its accompanying glandular and other organs, together with the extra-embryonic structures, such as the amnion, yolk-sack and allantois, constituting the coverings of the embryo and membranes of the developed ovum.

Fig. 638.

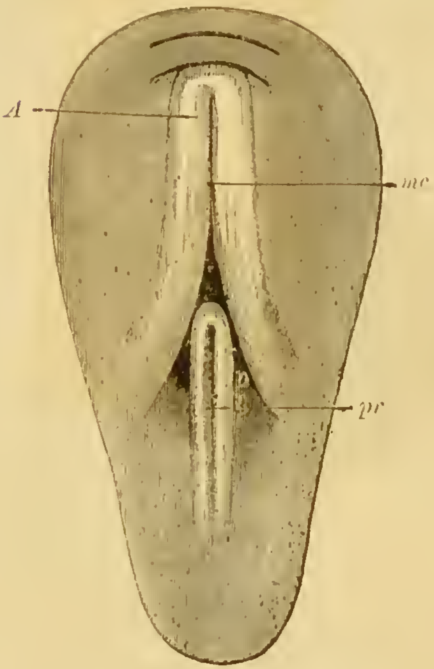


Fig. 638.—Surface view of the transparent area of a blastoderm of 18 hours, somewhat diagrammatic (from Balfour.)

pr, primitive groove, closed in front by the coalescence of the two lateral ridges; *mc*, medullary groove, having on each side the medullary folds or ridges A, which also meet in front to enclose the groove, but diverge behind so as to enclose the primitive streak; in front the fold of the amnion is commencing.

Fig. 639.

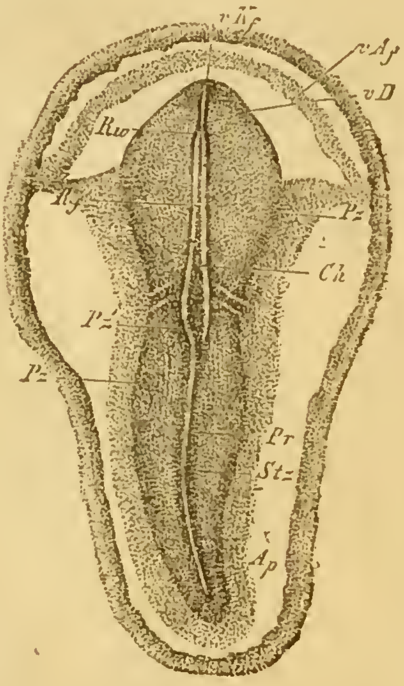


Fig. 639.—Area pellucida and rudiments of the embryo-chick of the second day. $\frac{19}{1}$ (From Kölliker.)

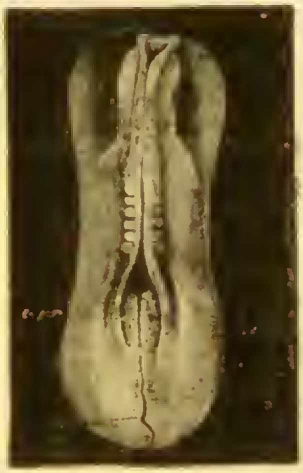
pr. primitive streak and groove; *Rw*, dorsal or medullary ridges meeting in front; *Rf*, medullary groove near its middle; *stz*, axial zone; *Pz*, parietal zone; *Pz*^{1}, two vertebral somites; *Ch*, notochord; *Vkf*, cephalic fold; *vD*, anterior intestinal fold shining through; *vAf*, anterior or amniotic fold; *Ap*, area pellucida.

2. Relation of the Layers of the Blastoderm to the Development of Different Systems and Organs.—In this complex developmental process, according to the views of Remak, with such slight modification as is necessary to bring them into conformity with the results of more recent discovery, the upper layer of the blastoderm, which we name epiblast (or *neuro-epidermal*), is the exclusive source of the organs of the nervous system, central and peripheral, with the organs of sense, the cuticular covering of the body and lining of the mouth, together with its accessory glands and other parts. The lower layer or hypoblast (the *epithelio-glandular*) gives rise to the epithelial lining of the alimentary canal and air-passages, the principal gland-ducts and the cellular elements of the glands.

Fig. 640.—DORSAL VIEW OF A BLASTODERM AND EMBRYO CHICK HAVING FIVE MESOBLASTIC SOMITES (from Balfour).

a.pr, anterior part of the primitive streak; *p.pr.* posterior part; the medullary ridges have come together in the greater part of their extent, but have not yet united; the caudal swellings are visible on each side of *a.pr*.

Fig. 640.



The mesoblast undergoes subdivision and has a much more complex destination. By its inner column it forms the matrix of the cranio-vertebral skeleton and the associated voluntary muscles. By the upper plate of its lateral part (*Somatic or parietal Mesoblast*) it gives rise, in association with the epiblast, to the osseous, fibrous, muscular, and tegumentary substance of the body-wall and limbs; while its lower plate (*visceral mesoblast*), separated from the upper by the body-cavity, supplies the formative material for the fibrous and muscular wall of the alimentary canal, the lymph and blood-vascular system, and the urinary and generative organs.

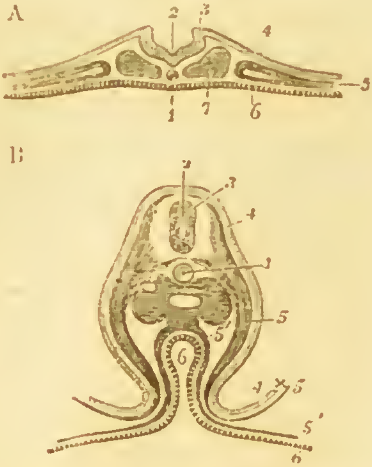
The two divisions or plates of the mesoblast now referred to (parietal and visceral mesoblast) in extending themselves peripherally in the embryo and ovum, are more or less associated with the upper and lower layers, the upper with the epiblast, the lower with the hypoblast, so as to form two composite sheets of the blastoderm, the upper of which we shall name the *parietal or somatic wall*, and the lower the *visceral or splanchnic wall* (the Somatopleure and Splanchnopleure of Foster and Balfour, No. 30). Of these the upper gives rise by its inflection to the amnion

Fig. 641.—TRANSVERSE SECTION THROUGH THE EMBRYO-CHICK BEFORE AND SOME TIME AFTER THE CLOSURE OF THE MEDULLARY CANAL, TO SHOW THE UPWARD AND DOWNWARD INFLECTIONS OF THE BLASTODERM (after Remak).

A. At the end of the first day. 1, notochord; 2, medullary canal; 3, edge of the dorsal lamina; 4, epiblast; 5, mesoblast divided into upper and lower plates: 6, hypoblast; 7, section of protovertebral somite.

B. On the third day in the lumbar region. 1, notochord in its sheath; 2, medullary canal now closed in; 3, section of the medullary substance of the spinal chord; 4, cuticular layer of epiblast; 5, somatic mesoblast; 5′, visceral mesoblast (one figure is placed in the body cavity); 6, hypoblast layer in the intestine and spreading over the yolk; 4 × 5, somatic wall going to form the amnion; 5′, 6, visceral wall passing into the yolk-sack.

Fig. 641.



or proper embryonic covering, which is continuous with the abdominal wall of the embryo at the umbilicus; while the lower sheet forms in its extension the greater part of two other membranes which are in direct continuity with the wall of the alimentary canal, viz., the yolk-sack and the allantois, all of which will be described later.

It requires to be noticed however that the foregoing account, though true of the great majority of mammalia, does not apply to them all. It has been long known, according to the discovery of Bischoff (No. 21, iv.), that in the guinea-pig the order of the position of the blastodermic layers is inverted in such a manner as to place the epiblast internally and the hypoblast externally, with a corresponding difference in the relative position of the parts developed from the several layers: and it has been recently shown by A. Fraser that a similar inversion of the layers exists in the rat and mouse. (Brit. Assoc. Aug. 1882.)

The existence of several laminæ in the germinal substratum was first suggested by C. F. Wolff in his celebrated work Theoria Generationis, published in 1759, and in his later Memoir on the Development of the Intestine first published in 1767 and republished in German by J. F. Meckel in 1812. It is, however, to the more exact researches of Pander, conducted under the direction of Döllinger of Würzburg, and published in 1817, and the modifications of them by Von Baer (1826-1837), that we owe the first consistent attempt to connect the development of the several organs and systems of the embryo with the different constituent parts or layers of the blastoderm. Pander recognised a trilaminar structure of the blastoderm and distinguished the three layers composing it, in their order from above downwards, or from without inwards in the egg, as the *serous, vascular*, and *mucous* layers (see Nos. 9, 10 and 12).

In 1850-54 a further important advance was made in the knowledge of the constitution of the blastodermic layers, by the discovery by Remak (No. 25) that the greater part of the middle layer soon after its formation comes to be divided into two laminæ, and separated by a space which corresponds to the perivisceral cavity—a fact which had been partially foreseen by Von Baer. So marked a division of the middle layer and distinction of the parts which are afterwards developed from its two laminæ, might seem almost to warrant the recognition of four distinct layers in the blastoderm; but it will be found on the whole more convenient to consider the fundamental layers as only three, to which, following the nomenclature of Foster and Balfour, we shall henceforth apply the designations of epiblast, mesoblast, and hypoblast, terms which are synonymous with those of ectoderm, mesoderm, and entoderm, employed by many authors.

3. **Origin and Constitution of the Blastodermic Layers.**—Returning now to the consideration of the constitution of the blastoderm, we shall find some difference of opinion prevailing among embryologists on this subject, and more especially as to the mode of origin of the middle layer. We cannot enter into a full discussion of this question here, but we shall endeavour to present a very brief view of the results of the most recent researches regarding it.

In the class of birds, as already noticed, the discoid blastoderm presents from the first, or from a very early period of incubation, a bilaminar arrangement of its cells, and there is no difficulty in identifying the greater part of the upper and more advanced layer with that which is afterwards known as epiblast. The lower layer consists at first of larger, more scattered and loose granular cells, but these or a part of them soon assume the more definite form of a distinct layer of flattened cells occupying the lowest place and therefore corresponding, according to most embryologists, to that which is later known as hypoblast. As yet there is no appearance of mesoblast or middle layer; but between the eighth and twelfth hour of incubation in the fowl's egg, during which time the primitive streak has been formed, the blastoderm undergoes considerable change in connection with the development of the middle layer. The primitive streak consists in fact of a linear or strap-like mass of cells, formed by direct proliferation from the lower cells of the epiblast, and continuing to adhere to that layer along the whole length of the streak. This is the axial plate of His and Kölliker, and, as first shown by the latter observer, is undoubtedly the commencement of a middle layer developed in connection with the epiblast.

Fig. 642.

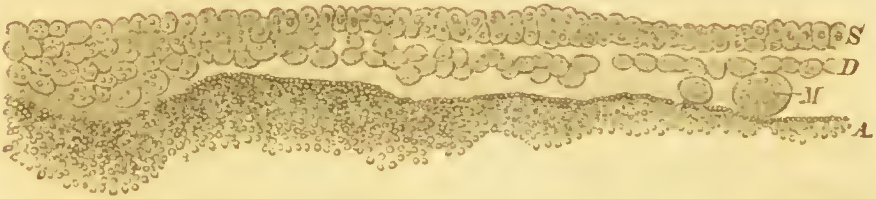


Fig. 642.—Microscopic view of a vertical section through half the blastoderm of a newly-laid egg. (From Stricker.) $\frac{200}{1}$

S, upper layer of small nucleated cells ; D, lower layer of larger granular cells ; M, segment spherules lying in the subgerminal cavity ; A, substance of the white yolk below the germ.

At this time, that is, after the formation of the primitive streak and previous to the appearance of the medullary plates and chorda dorsalis, the blastoderm in the forepart of the germinal area, both of birds and mammals, consists of only two layers, and it is not till some time later that the mesoblast which gives rise to the protovertebral plates is found to have extended itself into this region.

Fig. 643.

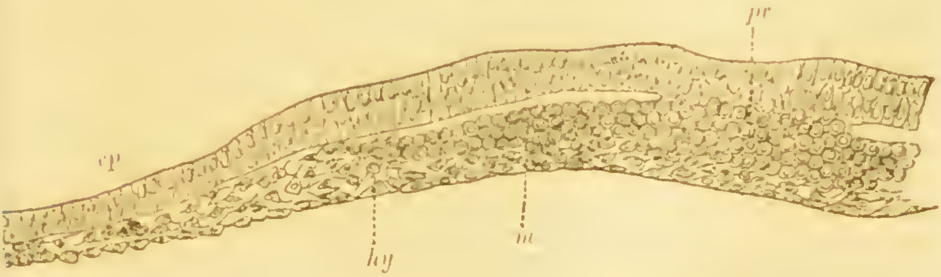


Fig. 643.—Transverse section through the front end of the primitive streak and blastoderm of the chick. (From Balfour.)

pr, primitive groove ; *m*, mesoblast ; *ep*, epiblast ; *hy*, hypoblast.

With regard to the much debated question of the mode of origin and extension of the mesoblast two different views mainly prevail among the embryologists who have most recently investigated the subject ; according to one of which, maintained by Kölliker (Nos. 28 and 99), Braun (No. 110) and others, the mesoblast is entirely derived from the axial plate of the epiblast before referred to, and spreads from that source outwards into all the other parts of the embryo or ovum where it afterwards forms the foundation of new parts. According to the other view, held by Balfour (Nos. 32 and 96), His (No. 111) and others, while it is admitted that the mesoblast has the axial origin from epiblast before mentioned, it is maintained that there are probably two other sources from which it proceeds, viz., from the primary lower layer in the greater part of its extent, and from nuclei of the germinal wall of the yolk at its periphery.

Fig. 644.

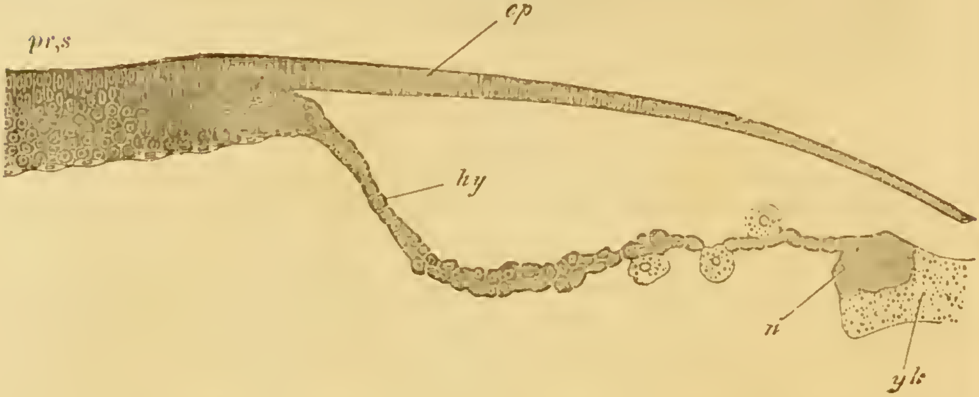


Fig. 644.—LONGITUDINAL SECTION OF THE BLASTODERM OF THE CHICK THROUGH THE PRIMITIVE STREAK AND THE PART IN FRONT OF IT (from Balfour).

pr.s, primitive streak ; *ep*, epiblast ; *hy*, hypoblast in front of the primitive streak ; *n*, nuclei in the yolk wall ; *yk*, yolk.

In a recent revision of the whole evidence on this question as applied to birds, Balfour and Deighton (No. 108), founding their opinion upon new and very careful observations made by them on the common fowl and duck, state that after the lateral expansion of the layer of mesoblast formed in connection with the axial plate there takes place both in the region of the primitive streak and in the fore part of the germinal area a rapid proliferation of cells presenting a stellate character, and connected below with the upper surface of the lower layer over the whole extent of tho transparent area. These cells are at first separate from the lateral parts of the axial mesoblastic plate, but below the primitive streak they are so intimately united with both epiblast and hypoblast as to render all three layers continuous in that situation. Balfour and Deighton therefore, while admitting with Kölliker the origin of a main sheet of mesoblast from the axial primitive streak plate, are inclined to differ from him so far as to attribute the origin of the lateral mesoblastic plates which form the mesoblastic somites in the region of the embryo to the differentiation of hypoblastic or lower layer cells, which however they allow are continuous with the wing-like or lateral extensions of the primitive streak or axial mesoblast. These authors further believe that a third set of mesoblastic elements may be derived from the peripheral portion of the blastoderm, viz., from the nuclei and cells of the germinal wall, from which elements the primitive blood and blood-vessels of the vascular area originate.

The latter view is one which has long been advocated by various embryologists, more especially by His (No. 29 and No. 111, i. and ii.), who in 1868 described the origin of the vascular as well as the connective tissues as taking place in the lower layer, and forming a special part of the mesoblastic elements under the name of *parablastic*. Similar views as regards the origin of the blood and vessels from peripheral blastodermic elements were brought forward by Peremeschko and maintained by Stricker and others of the Vienna school (Nos. 91 and 93).

In *mammals* the vesicular form of blastoderm, which results from the holoblastic segmentation of the ovum, seems to determine some modification in the mode of formation of the layers. As already stated, the completion of the primary segmentation leads to the covering in of the whole ovum with a layer of flattened nucleated cells, within which, besides the fluid remains of the original yolk-substance, there is the inner mass of granular cells or segmental spheres, which by their further development and extension come to produce one or more deep or internal layers, which gradually spreading over the interior give a bilaminar or trilaminar structure to an increasing area of the blastoderm.

Fig. 645.

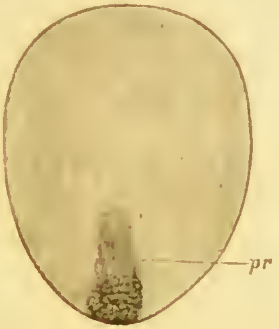


Fig. 646.

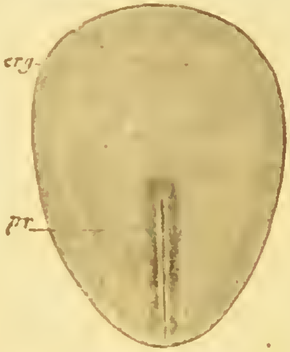


Fig. 645.—Embryonic area from the ovum of a rabbit of seven days. $\frac{30}{1}$. (From Kölliker.)

pr, first rudiment of the primitive streak.

Fig. 646.—Embryonic area from the ovum of a rabbit of eight days. $\frac{22}{1}$. (From Kölliker.)

arg, border of the embryonic area ; *pr*, primitive streak with groove.

Fig. 647.

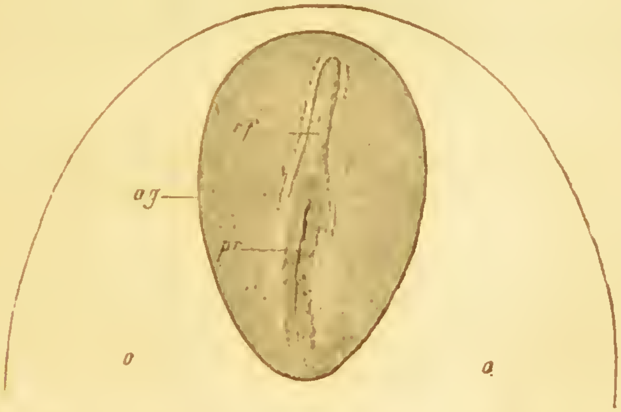


Fig. 647.—Embryonic area, with outline of part of the vascular area, from a rabbit's ovum of seven days $\frac{25}{1}$. (From Kölliker.)

oo, vascular area ; *ag*, embryonic area ; *pr*, primitive streak and groove ; *rf*, medullary groove.

It is in the central part of the blastoderm, at the fifth day in the rabbit, and when the inner layer has advanced over about half of the interior, that a discoid thickening or opacity occurs which gives rise to the *embryonal area* (*tache embryonnaire* of Coste); and it is now ascertained by the observations of Hensen, Kölliker and others, that the first appearance of the primitive streak and its groove and the commencement of the medullary canal and vertebral rudiments take place in a manner essentially the same as in birds. But the same or even a greater degree of doubt exists in mammals as in birds as to the mode of origin of the mesoblast, and there arises also in them the further question, viz., in how far the external vesicular layer of cells corresponds precisely to the later epiblast, as was for some time generally believed to be the case, or whether the deeper or internal layer of cells may also contribute to the formation of that layer.

Fig. 648.

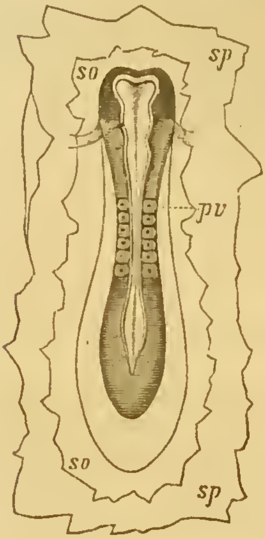


Fig. 648.—EMBRYO OF THE DOG SEEN FROM ABOVE, WITH A PORTION OF THE BLASTODERM ATTACHED.

The medullary canal is not yet closed, but shows the dilatation at the cephalic extremity with a partial division into the three primary cerebral vesicles; the posterior extremity shows a rhomboidal enlargement. The cephalic fold crosses below the middle cerebral vesicle. Six primordial vertebral divisions are visible; *so*, the upper division of the blastoderm; *sp*, the lower division, where they have been cut away from the peripheral parts.

Some part of the difficulty now mentioned has arisen from the observations of A. Rauber (No. 101), who in 1875 detected the presence, in addition to two other layers of the blastoderm in the rabbit, of a thin layer of flat cells closely adherent to the outer surface, which he found to have only a temporary existence, and gradually to disappear in the course of the development of the other layers. Lieberkühn a few years later (No. 104) showed that the outer layer of flat cells described by Rauber, which form the whole of the outer covering of the blastodermic vesicle resulting from the primary segmentation, is not the principal source of the permanent epiblast, but that that layer as well as the hypoblast or lower layer are the product of differentiation of the cells which form the internal mass of segmentation spheres or "yolk-rest."

Fig. 649.

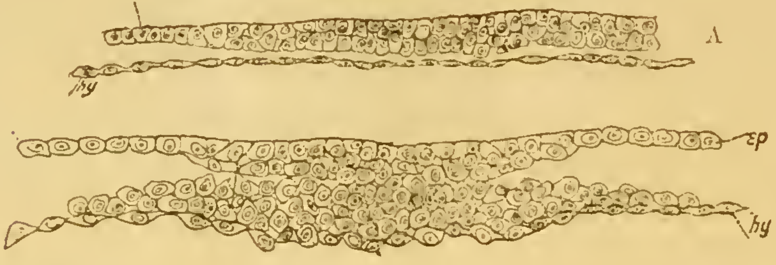


Fig. 649.—TWO TRANSVERSE SECTIONS THROUGH THE EMBRYONIC AREA OF THE RABBIT OF SEVEN DAYS. (From Balfour.)

A, through the anterior part of the embryonic area for about half its breadth; B, through the posterior part of the primitive streak; *ep*, epiblast; *hy*, hypoblast.

Kölliker, who was led by earlier observations on the blastodermic vesicle of the rabbit to coincide with the views of Rauber as to the transitory nature of the outer layer of flat cells, has more recently (1882) (No. 99, ii.) reviewed the whole subject and has described the result of renewed observations made on the rabbit as follows:—

The embryonal area of the rabbit's blastodermic vesicle consists at the fifth day of three layers, of which the upper, corresponding to Rauber's flat cells, is the same with the outer layer of the primitive blastodermic vesicle, while the other two layers arise by the widening out of the mass of inner cells, and its subsequent division into two laminæ. The outer layer of cells is transitory, and is not the source of the permanent epiblast, which is formed, as Rauber supposed, from the upper of the two internal layers of cells, while the lower of these gives rise to the hypoblast. After the disappearance of Rauber's cells the blastoderm becomes for a time distinctly bilaminar, the cells of the upper layer being more regularly set and columnar in form: those of the lower being large and flat, as well described by Hensen (98) and Schäfer (No. 100).

Fig. 650.

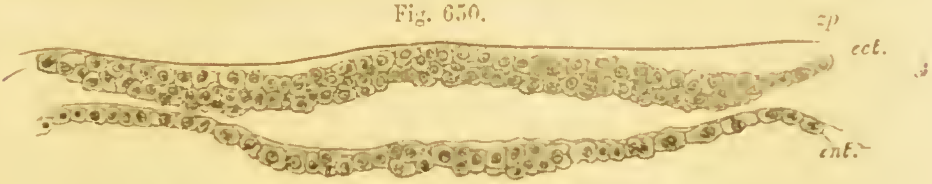


Fig. 650.—A SECTION THROUGH PART OF A BILAMINAR BLASTODERM OF THE CAT. (E. A. S.)

ect., *ent.*, ectoderm, entoderm; *z.p.*, thinned out zona pellucida.

The mesoblast first makes its appearance in the course of the seventh day in connection with the formation of the primitive streak, and according to Kölliker is formed entirely by proliferation of cells belonging to the epiblastic layer. This cellular multiplication takes place in an axial plate very similar to that previously described in the bird's egg, and the mesoblastic sheet which results extends in the same manner forward along with the primitive streak from the margin of the embryonal area where their development begins.

Fig. 651.

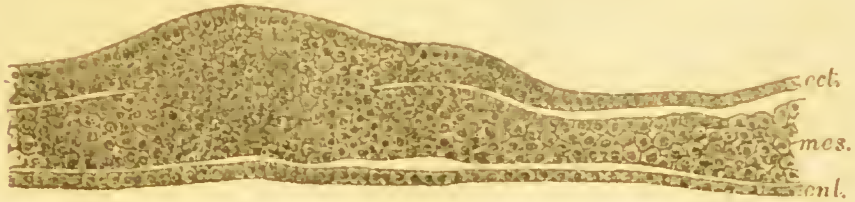


Fig. 651.—SECTION OF TRILAMINAR BLASTODERM OF THE RABBIT OF EIGHT DAYS AND NINE HOURS. (Kölliker.)

ect., *ent.*, as before; *mes.*, mesoderm continuous in middle (*pr.*) with ectoderm.

According to Kölliker the cells of the mesoblast have from a very early period of their existence a marked spindle and stellate character, and in this respect differ obviously from those of the epiblast and hypoblast; and thus the sheet of new formation is easily recognisable both on surface views and in sections, as it expands from its median attachment to the axial plate laterally over the surface of the germinal area. The sheet of mesoblast spreads out at first only to the sides of the primitive streak and backwards, being widest behind; but after a time it also extends forwards in the form of two lateral plates which spread into the anterior part of the germinal area, in which previously the blastoderm was only bilaminar, and finally it passes from the embryonic area into the whole extent of the surrounding vascular area.

The observations of Heape, made like those of Lieberkühn upon the blastoderm of the mole, confirm those of Kölliker upon the rabbit in so far that they show the larger portion of the mesoblast to be produced from epiblast in the axial plate of the primitive streak; but he is led by his researches also to advocate the view that a portion of the mesoblast is derived from hypoblast in the anterior region of the embryonal area in the same manner as Balfour holds to be the case in birds. He is also inclined to believe that the flat cells of Rauber combine in part with, or are converted into, the upper layer of the prismatic internal cells to form the epiblast (No. 107).

Fig. 652.

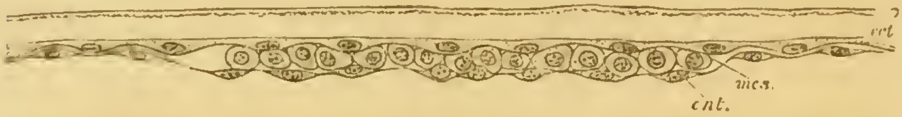


Fig. 652.—SECTION OF THE RABBIT'S BLASTODERM AT SIX DAYS. (From E. Van Beneden.)

ect., upper layer, or Rauber's cells; *mes.*, middle layer; *ent.*, lower layer.

E. Van Beneden takes quite a different view of these phenomena (No. 105). Not admitting the transitory nature of the upper layer as described by Rauber, he holds that this layer, which is co-extensive with the whole blastodermic vesicle, becomes the epiblast, that from the more restricted plate of deeper cells there is first formed a primitive lower layer, and that subsequently there takes place a separation or differentiation of this into a smaller central intermediate plate of rounded mesoblastic cells and a wider lower layer of flat hypoblastic cells (see fig. 652).

Fig. 653.

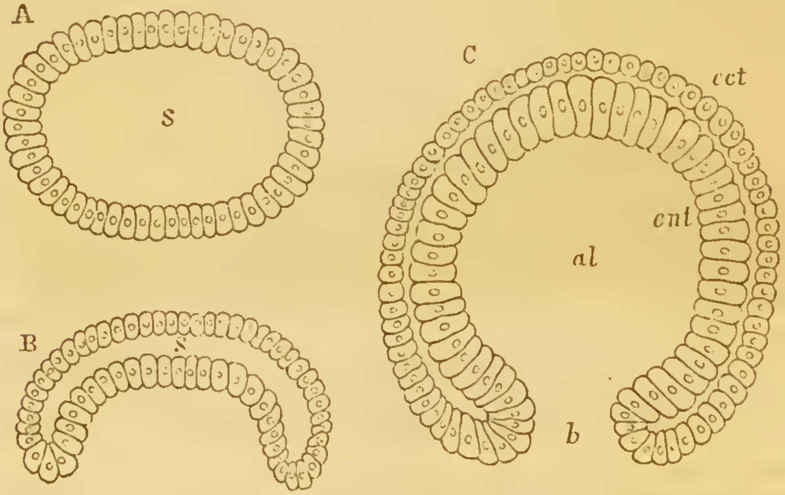


Fig. 653.—OVUM OF AMPHIOXUS IN THE THREE STAGES OF BLASTULA, INVAGINATION AND GASTRULA. (From Haeckel, after Kowalevsky.)

A. blastula stage, or single vesicular layer of cells resulting from segmentation; B, invagination stage forming two layers; C, gastrula stage in which a primitive alimentary cavity is enclosed by a bilaminar blastoderm; *s*, segmentation cavity; *ect.*, outer layer; *ent.*, inner layer; *al.*, primitive alimentary cavity formed by invagination; *b*, blastopore.

GENERAL RELATIONS OF THE BLASTODERM TO THE OVUM.

Invagination of the Blastoderm, Gastræa Theory.—The brilliant discovery by Kowalevsky in 1867 (No. 83) of the production of a bilaminar condition of the blastoderm in Amphioxus and some invertebrate animals, by the infolding or invagination of a primary simple cellular blastodermic membrane (blastula) resulting from the primary segmentation, and the attempt of Haeckel (No. 89) which followed to show that a somewhat analogous process is universal throughout all animals in which the distinction between ectoderm and entoderm exists, gave rise to an entirely new mode of viewing the relation of the blastoderm to the ovum and its embryonic development. In the Amphioxus the invagination consists in the doubling back or inwards of one half of the primary blastodermic vesicle upon the other, so that the two at last come into contact, by the gradual disappearance of the intervening cavity. At the same time the double wall thus produced bends round and converges at the margin of reduplication so as to enclose a new cavity which communicates with the exterior by a narrow aperture; this constituting the *gastrula* form of the developing ovum and embryo. The two layers forming the wall of this gastrula correspond with ectoderm and entoderm or the primary outer and inner layers of the blastoderm, and the now contracted aperture of invagination receives the name of blastopore appropriately given to it by Ray Lankester (No. 44). Now although it is very apparent that in the higher vertebrates, as well as in many of the lower animals, there is no actual infolding or invagination of the blastoderm such as that now described, yet there are circumstances connected with the origin of the layers, and their continuity at the place where the first traces of the embryo appear, which seem to make it possible to refer the phenomena of blastodermic and early embryonic development to a general principle in some degree consistent with the invagination and gastraea theories of Kowalevsky and Haeckel.

We cannot in this place enter upon the consideration of this extensive and difficult subject; but it may be proper to refer briefly to one or two points in connection with its history in the higher vertebrates as bearing upon these theoretical views.

Blastopore and Neurenteric Canal.—We have had occasion more than once to refer to the existence of the blastopore aperture or indications of it in the higher vertebrates. The more trustworthy of these indications are to be found entirely in the primitive streak and its groove, and in certain depressions and passages through the layers of the blastoderm which have been detected in their vicinity. It is more immediately in the space between the hinder extremity of the notochord and primitive medullary canal and the fore part of the primitive streak that in birds and reptiles the deepest aperture has been observed, in the form of a downward passage, which comes to be established some time after the formation of the mesoblast and protovertebral somites, and which leads from the exterior or from the hinder part of the still open medullary canal into the archenteron or primitive alimentary cavity round the hinder extremity of the notochord, and to which the name of *neurenteric canal* is given. The fact that the first development of a primitive trace takes place in all vertebrated animals at the margin, and not, as was formerly held, for the higher tribes, in the centre of the germinal area, affords some explanation of the very obscure relation subsisting between the outer and inner primary layers of the blastoderm, and opens up a way for the application of the theory of invagination to the early phenomena of development in the amniota as well as in the lower vertebrates.

In endeavouring to explain this matter we cannot do better than follow closely the able exposition of the subject given by Balfour, whose own researches have done much to demonstrate the applicability of the theory of invagination to the early development of the higher vertebrates. A careful consideration of the relations of the primitive trace and its groove to the ovum and earliest phenomena of development, its transitory existence as discovered by Dursy in 1867 (No. 90), the occasional perforation of the layers of the blastoderm in a part of it, and its intimate connection with the origin of the mesoblast, has led Balfour, and after him several other embryologists, to the view that the primitive trace is the vestige of a blastopore or aperture of invagination of the blastoderm, and that its groove and prolongation as a trace arise from the very early and rapid extension of the blastoderm round these structures.

In illustration of this subject we may refer to the diagram contrived by Balfour, to show the relations between the medullary groove, the primitive trace, and the rest of the blastoderm in three different forms of development as presented by the Amphibia, the Elasmobranchs, and the Amniota.

We shall suppose that in all the three sets of animals here referred to, the primitive blastoderm already consists of two layers or groups of cells, viz., an external epiblastic, and a deeper or internal set representing the primitive hypoblast, and (leaving in the meantime the mesoblast out of view) supposing further that the outer layer or epiblast has to a greater or less extent covered in the deeper layer, there is seen in A, which represents the frog's ovum, a round spot, *yk*, where the inner larger cells or yolk spheres are still exposed, and at *ne* a depression where the outer and inner cells are continuous. These together represent the blastopore or place of invagination; and it will be seen further that it is at this point and from it forwards, that is towards the head end of the embryo, that the medullary canal, *mg*, is developed. By the extension of the outer layer the round spot, long known as the anus of Rusconi, is covered gradually over by the epiblast, and the aperture of invagination reduced in size, is finally closed; the neurenteric canal being left, however, for a time more deeply. The permanent anus is of later formation.

Fig. 654.

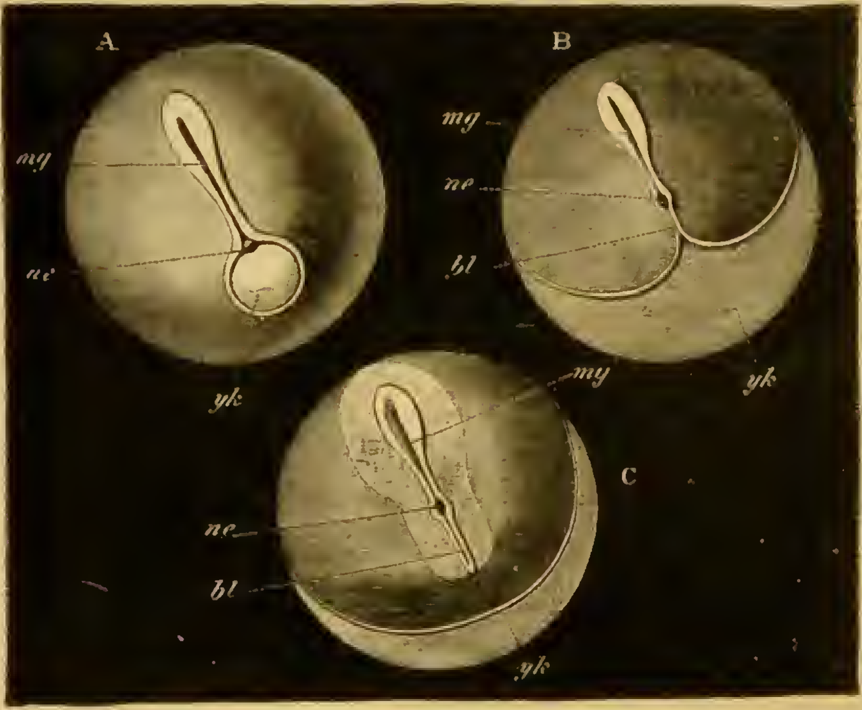


Fig. 654.—DIAGRAMS ILLUSTRATING THE POSITION OF THE BLASTOPORE, AND THE RELATION OF THE EMBRYO TO THE YOLK IN VARIOUS MEROBLASTIC VERTEBRATE OVA. (From Balfour.)

A, type of the Frog; B, elasmobranch type; C, amniotic vertebrate; *mg*, medullary plates and groove; *ne*, neurenteric canal; *bl*, portion of blastopore adjoining this canal; *yk*, part of yolk not yet enclosed by the blastoderm; in B and C, *bl* is the seat of the primitive streak.

In the elasmobranch fishes (B), of which the ovum is meroblastic, the blastoderm is seen to have extended only a certain way over the yolk, but in such a manner as to involve or surround the blastopore aperture, which may be supposed to have been previously marginal or at the union of the outer and inner blastodermic layers, and thus to give rise to a prolongation of the aperture in the form of a groove, *bl*, by the meeting of the blastoderm from the two sides.

In the amniota, C, the separation of the embryonic area still further from the margin of the blastoderm is effected by the rapid extension of the latter beyond the aperture of invagination. and thus the blastopore and its prolongation as a primitive trace and groove are brought more fully within the embryonic area, while the medullary groove stands in the same relation as in the lower animals. It will be seen, however, that the first indication of the primitive trace even in the amniota arises marginally, and it is probable therefore that it essentially corresponds in position with that of the lower vertebrates.

From this it appears that the first traces of embryonic formation in these several groups of animals stand in a constant and determinate relation to the blastopore, or if we do not go so far as to admit the occurrence of actual invagination, to the place of continuity between the upper and lower primary layers of the blastoderm, and to the seat of primary differentiation of the principal part of the mesoblast.

Fig. 655.

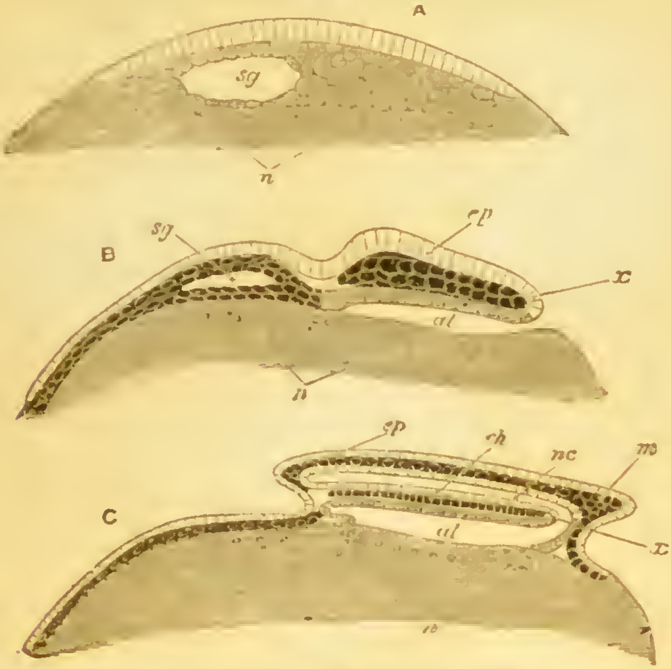


Fig. 655.—Diagrammatic Longitudinal Sections of Elasmobranch Embryo and Blastoderm. (From Balfour.)

A, younger stage with two primary layers ; B, more advanced stage with three layers and invagination at the hinder end of the embryo ; C, still more advanced ; the embryo raised from the blastoderm with neural and primitive alimentary canals and neurenteric communication between them.

ep, epiblast ; *m*, mesoblast ; *x*, epiblast continuous with hypoblast ; *nc*, neural canal ; *ch*, notochord ; *al*, alimentary cavity ; *sg*, segmentation cavity ; *n*, nuclei of the yolk.

It may be proper to make mention here of the remarkable observation by E. Van Beneden of the existence of a small aperture or deficiency in the external layer of cells on that side of the rabbit's ovum where the inner cells or segmental spheres (forming the yolk-rest) adhere to the outer, which appeared to him to have the effect of establishing continuity between the outer and inner layers of the blastoderm in the manner of a blastopore. But there are difficulties in the way of reconciling this view of a mammiferous blastopore with those of Balfour and others on this subject as founded on the observation of invagination in the lower vertebrates. (See No. 75.)

The existence of a neurenteric canal or blastopore in birds was discovered by Gasser in 1879 (No. 103), and has been confirmed by Balfour and Braun : and from these observations it appears that it is subject to some variation in position and extent in that class of animals.

This discovery was extended to the class of Reptiles (Lizards) by Kupffer and Beneeke in 1879 (No. 112), and confirmed by original observations by Balfour; and a further series of researches by Kupffer (No. 113) in the present year, have shown that the neurenteric canal exists in Ophidia and Chelonia.

We owe to Hensen the first clear account of the development of the primitive streak in mammals (rabbit), and his observations have been ably followed up by Kölliker. The observations of Schäfer on the early blastoderm of the guinea-pig have shown more clearly the connection subsisting between the lower layer in the medullary or embryonic region and the epiblast and mesoblast in the anterior extremity of the primitive streak, and according to Balfour a comparison of this with the conditions observed in reptiles and birds leaves little doubt that this union may be looked upon as the dorsal lip of a blastopore. In the mole (and partially also in the rabbit) Heape has ascertained the existence of a neurenteric canal similar to that observed in other vertebrates (No. 107). This appears first as a pit at the anterior extremity of the primitive streak, and in later stages perforates the floor of the hinder end of the medullary groove. A. Fraser also has seen the neurenteric canal in the rat.

Fig. 656.

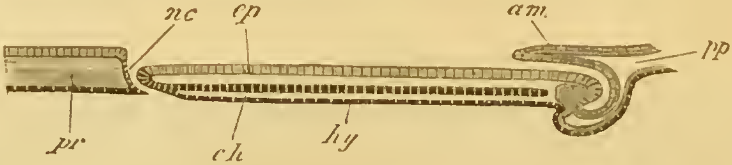


Fig. 656.—DIAGRAMMATIC LONGITUDINAL SECTION OF AN EMBRYO OF LACERTA. (From Balfour.)

pp, body cavity; *am*, amnion fold; *nc*, neurenteric canal; *ch*, notochord; *hy*, hypoblast; *ep*, epiblast of the medullary plate; *pr*, primitive streak. In the primitive streak all the layers are partially fused.

Direction of the Embryonic Axis.—It is well known that in the common fowl and other birds the line of the primitive streak continued through the

Fig. 657.

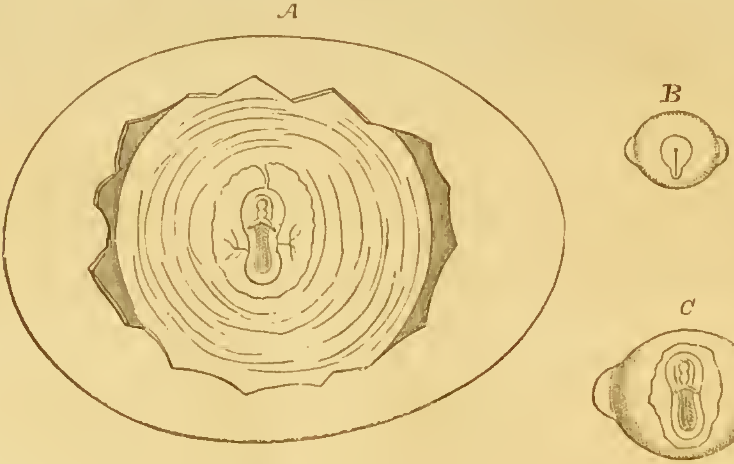


Fig. 657.—OUTLINES SHOWING THE RELATION OF THE AXIS OF THE EMBRYO TO THE OVUM IN BIRDS AND MAMMALS. (A.T.)

A, Fowl's egg opened after 35 hours' incubation, showing the embryo chick within the transparent and vascular area on the surface of the yolk; at right angles to the long axis of the egg; B & C, two early stages of development in the ovum of the dog, showing the primitive streak (in B) and the commencing embryo (in C); the line of the uterine tube and long diameter of the ovum being at right angles to the vertebral axis of the embryo.

medullary groove which represents the vertebral axis of the embryo is during the first two days of incubation always placed at right angles to the long axis of the egg, and in a determinate position, so that if one looks down upon the germinal area in an incubated egg the small end of which is placed towards the right hand, the cephalic extremity of the embryo is directed forwards, and the caudal extremity and primitive streak backwards.

There is some reason to believe that the line of the first cleavage of the germinal area may be the same with that of the first embryonic axis as now described both in birds and amphibia, but this is not fully known. It deserves to be noted, however, that the position of the cicatricula in the yolk or ovarian egg is also fixed, being invariably close to the pedicle of the ovicapsule, and all this seems to indicate some constant relation between the position of the egg, the mode of cleavage, and the attitude of the first lineaments of the embryo.

In mammals also numerous observations show that the axial line of the embryo is constant, and is placed so as to cross the long axis of the uterus, as may be seen in the dog, pig, sheep, rabbit, rat and guinea-pig. But in both mammals and birds this first determinate position is soon lost, and a more variable one is assumed by the embryo when its development has advanced so as to separate the body from the rest of the blastoderm by an umbilical constriction. The cause of these relations of position is still entirely unknown.

III. SPECIAL HISTORY OF THE DEVELOPMENT OF THE OVUM.

In the ova of the higher vertebrates the phenomena of development fall naturally into two groups, according as—1st, they occur in parts belonging strictly to the body of the future embryo, and are therefore embryonic; or 2nd, they are connected with the production of parts which being situated external to the body of the embryo may be regarded as accessory and called extraembryonic. We shall begin with the second of these divisions as affording a convenient opportunity of explaining some general relations of connection between the embryo and the other parts of the developing ovum.

1. DEVELOPMENT OF EXTRAEMBRYONIC PARTS.

Membranes of the Ovum in General.—In the three higher classes of vertebrates the extraembryonic structures consist of the membranes named yolk-sac, amnion and allantois; and to these may be added a fourth, existing only in mammals, and which may best be named the chorion. We shall first state the most general facts as to the development of the membranes; and then in connection with human utero-gestation describe the formation of the placenta, which is the organic medium of connection between the ovum with its embryo and the maternal uterus.

It is to be noted that this description will not apply to many of the phenomena observed in the exceptional forms in the guinea-pig, rat and mouse.

The Yolk-sac.—This name is given to an organised and vascular covering formed by the extension of the layers of the blastoderm over the surface of the yolk, and existing in all vertebrate animals.

The yolk-sac is the seat of the first circulation of the blood in the vitelline or omphalo-mesenteric vessels of its vascular area, and in oviparous animals especially these vessels spread at a later period over the whole surface of the yolk in the membrane which forms the sac. In birds the food-material of the yolk is absorbed by these vessels and conveyed by them as nourishment into the system of the embryo, through a special structural arrangement of the membrane, which is thrown into folds and beset with tufted groups of cells surrounding the vessels of its interior. (Courty, in Ann. d. Sc. Nat. 1844.)

In mammals as in birds the vascular area spreads over the surface of the yolk, but does not in all cover it entirely. In some the yolk-sac grows with the embryo and other parts of the ovum to a large proportional size, which it retains up to an advanced stage of development, while in others its growth ceases at an early period, and this is followed in some by the atrophy and complete disappearance of the yolk. The cavity of the yolk-sac is in most occupied chiefly by a coagulable fluid without the peculiar yolk corpuscles which belong to the yolk-substance of birds and reptiles.

The differences which are observed in the extent of development of the yolk-sac and its blood-vessels may be traced to differences in their relation to the chorion in utero-gestation. In rodentia, and to some extent also in insectivora and cheiroptera, it comes into contact or union with the non-placental part of the chorion, and furnishes blood-vessels to that membrane. In ruminants it is very soon drawn out into two attenuated tubes which extend towards the ends of the greatly-elongated ovum. In carnivora it is of considerable size, stretching through the ovum towards its opposite poles, but without vascular union with the chorion.

Fig. 658.

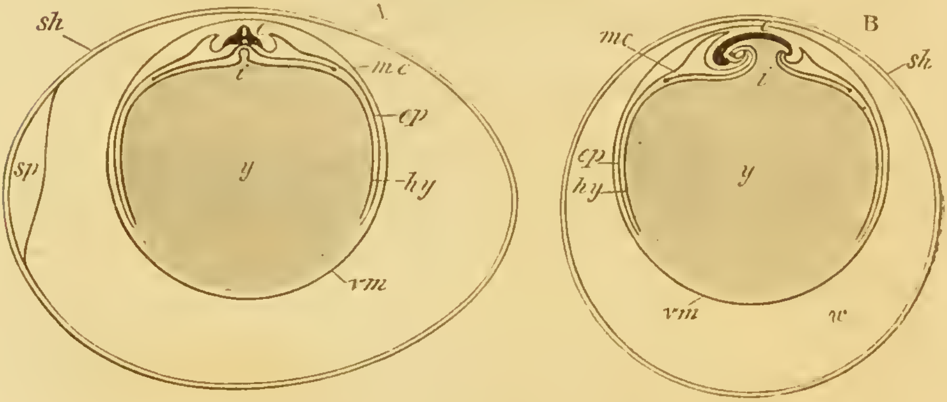


Fig. 658.—Vertical sections of an incubated fowl's egg, longitudinally and transversely, at the third day.

The figure is diagrammatic and is intended to show the early relations of the membranes to the embryo and rest of the egg. The parts of the embryo and those near it are represented as proportionally larger than natural. A, longitudinally in the egg, and across the embryo; B, across the egg and longitudinally in the embryo; *sh*, shell and external covering of the egg; *sp*, air space at the larger end; *y*, the yolk partially covered by the spreading layers of the blastoderm, viz., *ep*, epiblast, *hy*, hypoblast, and *mc*, visceral mesoblast as far as the vascular area extends; *vm*, vitelline membrane; *w*, space occupied by the albumen of the egg; *e*, the embryo (shaded dark) consisting of its medullary and protovertebral axis, and partially surrounded by the commencing folds of the amnion in connection with epiblast (*ep*); *i*, the place of communication of the primitive intestine with the yolk-sac. For the sake of clearness the parietal mesoblast has been omitted.

In the human species the yolk-sac, which is also named the umbilical vesicle, retains its vascularity for a short time, and continues to grow up to the fifth or sixth week, at which time it has assumed a pyriform shape, and is connected by a tubular vitelline duct with the intestine.

In an ovum of from five to six weeks it is about a quarter of an inch in diameter, and lies loosely in the space between the amnion and chorion. At a later period, the duct elongating with the umbilical cord, the vesicle remains flattened and atrophied in the same relation to these membranes as before. In the third month its duct is found connected with a coil of intestine which in the form of a hernia occupies the umbilical cord outside the abdomen of the embryo (see fig. 789, p. 882). At a later period the much elongated and attenuated duct with the vitelline vessels, now shrunk and impervious, may still be traced through the umbilical cord, while the flattened vesicle may be found even up to the end of the term of uterogestation.

The Amnion.—This vesicular covering of the embryo does not exist in amphibia or fishes, but is present in all reptiles, birds, and mammals, which are hence named *Amniota*. It begins to be formed at an early stage of development, and subsequently becomes distended by a fluid in which the embryo floats and is attached by means of the umbilical cord to its amniotic enclosure.

Fig. 659.

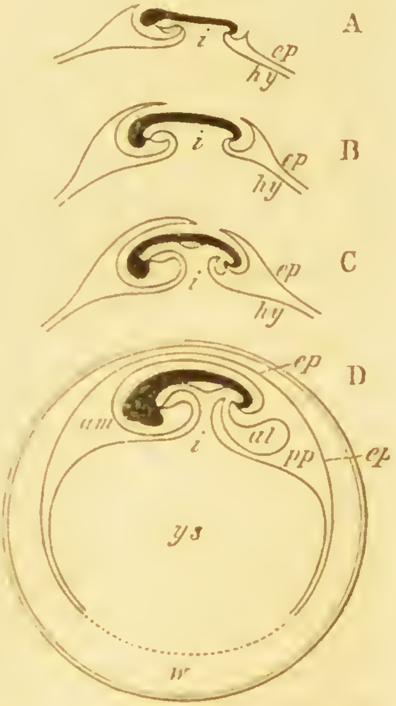


Fig. 659.—Diagrammatic outlines of longitudinal sections of the embryo-chick at successive periods during the formation of the membranes. (A. T.)

A, at the beginning, B, towards the end of the second day of incubation; C, on the third day; D, on the fourth day, showing also a section of the whole egg. In all these figures the embryo and the neighbouring inflections of the membranes are represented proportionally larger than natural. The dark-shaded part indicates the embryo: *ep*, epiblast; *hy*, hypoblast; (for the sake of clearness the mesoblastic folds accompanying these are not represented). In A, the cephalic fold of the amnion has begun; in B, it has increased, and the caudal fold has commenced: in C, the two folds approach one another, leaving the amnion still open dorsally: in D, the outer fold or false amnion has separated from the inner or true amnion which is now complete; *ys*, the cavity of the yolk being gradually surrounded by the yolk-sac formed of all the three layers of the blastoderm, and communicating at *i*, with the alimentary canal; *al*, in D, shows the allantois beginning to expand from the intestine; in C, it is just beginning to appear.

The structure and mode of formation of the amnion are essentially similar in the three classes of animals in which it exists. It generally consists of two layers, derived respectively, the inner from the epiblast, and the outer from the parietal layer of the mesoblast; the first formed of distinct nucleated cells, the second presenting in later stages a fibrous structure. The external layer possesses considerable muscular contractility and in some animals is partially vascular.

The formation of the amnion takes place by the gradual inflection in a dorsal direction from the flat part of the blastoderm adjoining the embryo of the two layers before mentioned, first at the cephalic, and somewhat later at the caudal extremity and at the sides (see fig. 659, A, B, C and D), so that the two layers of which the amnion is composed are lifted up and separated from the remaining two lower layers (visceral mesoblast and hypoblast) of the blastoderm, by a space which is a peripheral extension of the pleuro-peritoneal cavity. The embryo thus comes to sink into a hollow produced by the rising of the amniotic folds round it. The backward folds deepening more and more, gradually converge on the dorsum of the embryo, and at last come together, the margins of the reflection narrowing rapidly and being finally completely obliterated or lost by their convergence and by the subsequent dissociation of the inner from the outer divisions of the folds (fig. 659, D). The separated inner division now becomes the entire closed sac of the amnion, connected only with the rest of the parts at the umbilical constriction where it is continuous with the integument of the embryo. The outer dissociated division is the *false amnion* of Pander and Von Baer, passing out into the peripheral part of the blastoderm, and constituting for a time an external covering of the ovum, which in birds and reptiles appears afterwards to be lost by thinning or absorption ; but which in mammals is probably connected with the development of the permanent chorion in a manner to be referred to hereafter.

In birds at a more advanced stage of incubation the true or enclosed amnion is surrounded externally by the expanded allantois. In mammals its relations vary somewhat according to the nature and extent of the proportional development of the yolk-sac and allantois. In the advanced stage of the development of the human ovum the amnion is to a great extent in contact with the interior of the chorion ; but its origin and formation do not differ materially from those of animals.

In the human embryo, as in that of most animals, the amnion is at first and for some time after its completion very close to the surface of the body, but after a time, corresponding to the fourth day of incubation in the chick and the fourth or fifth week of gestation in man, the increased accumulation of fluid within the amnion expands the membrane rapidly so as to remove it to a considerable distance from the embryo.

The muscular contractility of the amnion doubtless resides in its outer layer derived from the parietal mesoblast. The contractions appear to be rhythmic, and they may be seen in the opened incubated egg of the fowl, or even in the entire egg, by means of a bright light in a dark chamber, from the sixth or seventh day of incubation ; and it is probable that they are of a similar nature in mammals.

The human amniotic fluid contains about 1 per cent. of solid matter, consisting chiefly of albumen, with traces of urea, which is probably derived from the urinary secretion of the fœtus.

It would appear that there is a difference in the structure of the reflected or false amnion in birds and in mammals. In the former it is composed of the same two layers as the amnion itself, their position being reversed, but in mammals the development of the mesoblast appears to cease at the place of reflection of the true into the false amnion, so that the latter consists only of the epiblast.

The Allantois.—This membrane, sometimes also called urinary vesicle, exists as a fœtal structure in all the amniota, but not in fishes or amphibia ; and yet in the latter animals a corresponding vesicle is developed in the adult. In reptiles, birds, and mammals it originates at a very early period as a diverticulum from the hinder part of the primitive intestine, but there are great differences in the degree and rate of its extension, a rapid and wide expansion occurring in some, while in others it remains of comparatively small size. It is the seat of an extended distribution of ramified and capillary blood-vessels which perform important functions in connection with the nutrition of the embryo and the aëration of its blood.

The allantois at its origin consists essentially of a thickened bulging portion of the visceral mesoblast, and a corresponding extension of the intestinal hypoblast within; and from recent researches in reptiles (Kupffer No. 113) would appear to have close relations with the neurenteric canal. The capillary network of commencing blood-vessels makes its appearance in its mesoblastic layer at a very early stage, and these become connected with the main vessels of the embryo by means of two arteries and two veins. The allantoic arteries are at first separate branches of the two primary divisions of the abdominal aorta, and subsequently, when the two aortas coalesce, they are derived from the hypogastric arteries, and have been called umbilical. The two returning vessels or allantoic veins pass into connection with the principal veins of the yolk-sac, and with them form the umbilical veins. The name of allantoic suggested by Balfour is preferable to that of umbilical for the vessels of the allantois.

Fig. 660.

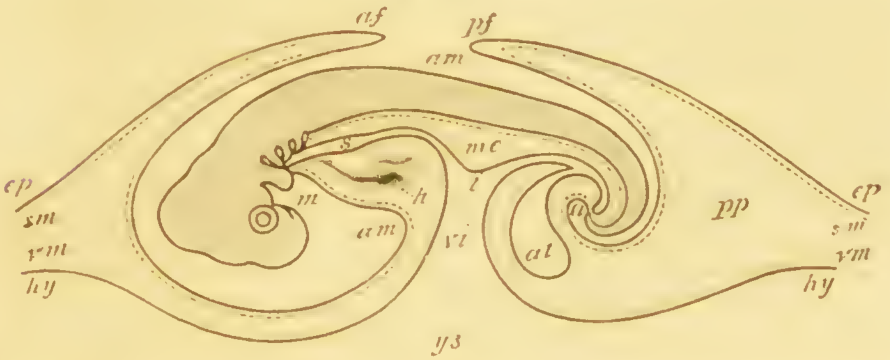


Fig. 660.—Enlarged diagrammatic outline of a longitudinal vertical section of the chick and neighbouring parts of the blastoderm on the fourth day. (A. T.)

ep, epiblast; *sm*, parietal mesoblast, together forming the *somatic plate*; *hy*, hypoblast; *vm*, visceral mesoblast, together forming the *visceral plate*; *af*, cephalic fold; *pf*, caudal fold of the amnion; *am*, cavity of the true amnion; *ys*, yolk-sac, leading by *vi*, the vitello-intestinal aperture to *i*, the intestine; *s*, the stomach and gullet; *a*, the future anus still closed; *m*, the buccal cavity or mouth formed in epiblast and still closed from the pharynx at the fauces, which are not shown; *me*, the mesentery; *al*, the allantoid vesicle communicating by its pedicle with the hinder intestine; *pp*, the space between the outer and inner folds of the amnion, which is an extension of the body cavity or pleuro-peritoneal space within the embryo between the parietal and visceral mesoblasts. The shaded part of the figure represents the head and trunk of the embryo in which the eye and the jaws with the branchial bars and clefts are indicated. The epiblast and hypoblast are drawn with entire lines, the parietal mesoblast with an interrupted and the visceral mesoblast with a dotted line.

The allantoid diverticulum soon takes the form of a flask-like vesicle, connected with the intestine by a narrow pedicle, as may be well seen in the chick on the fourth day, and in the embryo of the rabbit or dog at a corresponding period. In all birds, as also in reptiles, it undergoes rapid dilatation and extension, and its inner hypoblastic portion being filled with fluid, and the doubled membrane flattening out in the space which intervenes between the parietal and visceral mesoblast, as far as is allowed by the separation of these two layers, viz., to the margin of the vascular area of the yolk, it follows the gradual extension of that area over the surface of the yolk; and finally, as the albumen gives place by its absorption into the yolk cavity, the allantois comes to occupy more and more of the intermesoblastic interval, and to fill the whole space between the amnion and yolk-sac on the one hand and the lining membrane of the egg shell on the other.

The allantoic blood-vessels are distributed both in its internal and external folds, but form a richer network on the latter, and there they exhibit in the arteries and veins a marked difference of colour which indicates the action of the air upon the blood through the egg-coverings analogous to that of a respiratory organ.

Fig. 661.

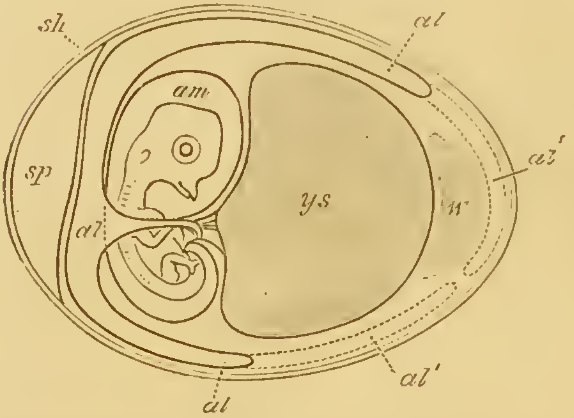


Fig. 661. — DIAGRAMMATIC OUTLINE OF A LONGITUDINAL SECTION OF THE FOWL'S EGG ABOUT THE MIDDLE OF INCUBATION. (A.T.)

sh, the shell and its membrane; *sp*, the air space much enlarged; *am*, the amnion with the enclosed embryo now placed towards the large end of the egg and air space; *ys*, the yolk and yolk-sac; *al*, the allantois expanded as a doubled vesicular membrane over a considerable part of the internal surface of the egg; *al'*, in dotted lines indicates the manner in which its expanding folds will ultimately meet and cover the whole of the deeper parts; *w*, the hardened remains of the white or albumen which towards the end of incubation lie between the yolk-sac and the allantois.

It is also worthy of notice that from the time when the allantois has attained some size, it, like the amnion, is possessed of contractility, which resides in its mesoblastic layer; and accordingly on opening an incubated egg, from the effect of change of temperature or other stimuli, active motions may be perceived, caused by the alternate contraction and relaxation of different parts of the membrane.

In some of the mammalia the origin and early development of the allantois is nearly the same as in birds, but in a more advanced stage of development the relations of this membrane to the other parts of the ovum are greatly modified by its combination with the chorion, more especially in the region of the placenta.

In most mammals the external or mesoblastic lamina of the allantois undergoes greater extension than the inner hypoblastic sac, and this is remarkably the case in the human subject, in which it is still doubtful whether any internal vesicle is present beyond the limits of the umbilical cord. In the human ovum the external or mesoblastic vascular element probably spreads at a very early period over the whole interior of the chorion (placental and non-placental parts), while the internal or hypoblastic vesicle either shrinks and atrophies at a very early period or is comparatively small and has never reached the interior of the chorion. This subject will again be referred to in the account of human uterogestation.

Fig. 662.

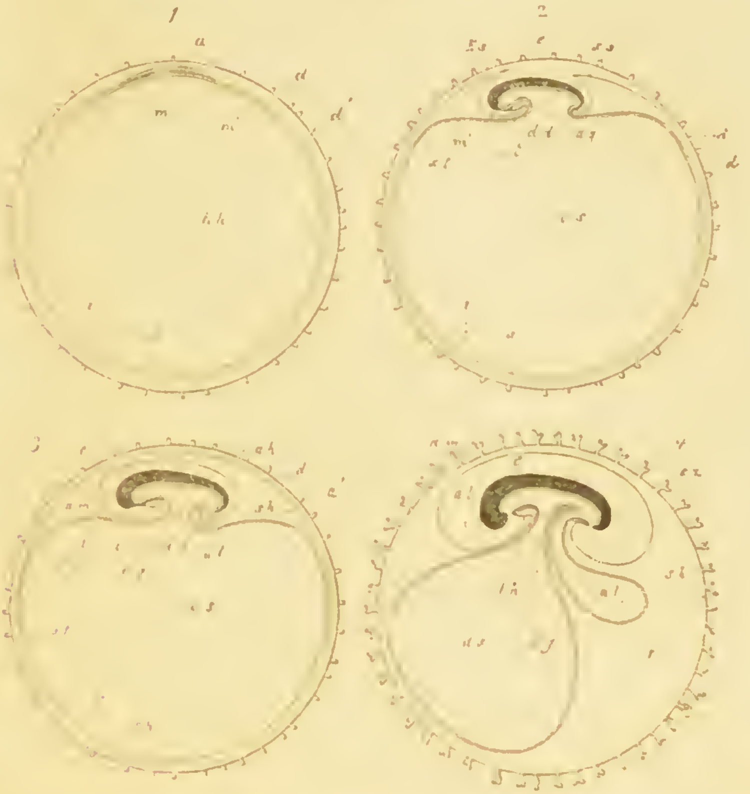


Fig. 662.—DIAGRAMMATIC SECTIONS OF THE MAMMIFEROUS OVUM IN DIFFERENT STAGES OF DEVELOPMENT TO SHOW THE PROGRESS OF FORMATION OF THE MEMBRANES. (From Kolliker.)

1. Ovum in which the chorion has begun to be formed, with the blastoderm and rudiment of the embryo within. 2. Ovum in which the cephalic and caudal folds have contracted the umbilical aperture towards the yolk-sac, and the amniotic folds are turning towards the dorsal aspect. 3. The amniotic folds being completed have met in the dorsal region; the umbilical opening is more contracted, and the allantois has begun to sprout. 4. The true amnion is detached from the reflected or false amnion which has disappeared or combined with the chorion; the cavity of the amnion is more distended; the yolk-sac is now pediculated, the allantois projects into the space between amnion, chorion, and yolk-sac, and the villi of the chorion begin to ramify.

d, external membrane or primitive chorion; *d'*, commencing villi of the chorion; *sh*, subzonal membrane or chorion; *sz*, villi of the chorion more advanced; *am*, amnion: *ah*, its cavity; *ks*, cephalic fold; *ss*, caudal fold of the amnion; *a*, the embryonal rudiment in the epiblast; *m*, that in the hypoblast, and *m'*, in the mesoblast; *st*, margin of the vascular area in its early stages; *dd*, hypoblast; *kh*, hollow of the vesicular blastoderm, becoming afterwards *ds*, the hollow of the yolk-sac; *dg*, ductus vitello-intestinalis; *al*, allantois; *e*, embryo; *r*, original space between amnion and chorion; *vl*, wall of the thorax in the region of the heart; *hh*, pericardial cavity.

The urinary bladder of mammals is produced by a dilatation in the pedicle of the allantois near the cloaca and within the body of the embryo. The urachus is the tubular extension of the walls of the bladder towards and in part through the umbilicus to join the allantois, but the extent to which its hollow is prolonged varies greatly among animals, and in the human embryo this does not in general pass beyond the root of the umbilical cord.

The Chorion.—Under this name there has been long known in human embryology a most characteristic but rather complex membrane which surrounds the ovum from the earliest period at which it has been observed within the cavity of the uterus, and which probably begins to be formed about the ninth or tenth day after conception. This is the villous or shaggy vascular chorion, a part of which takes an important share by its further development in the formation of the fœtal portion of the placenta, while the remainder may be recognised as persistent during the whole of uterogestation.

An external covering of the ovum having a very similar origin and structure, and with analogous relations to the other parts, exists for a time in all mammals, and though in many less developed and less persistent than in the human ovum, still deserves the same name.

The mammiferous ovum when it enters the uterus has still a covering from the ovarian zona pellucida, but in the rapid expansion which the blastodermic vesicle undergoes within the first or second day after the completion of the segmenting process, the zona seems either to be much attenuated and finally lost, or may possibly be combined with the outer layer of the blastoderm, which then surrounds the whole ovum. In some animals, such as the rabbit, dog, and cat, and the same is probably the case in man, previous to the appearance of any trace of the embryo, but when an embryonic area may have been formed, villi begin to project from the surface of the ovum, and from the primitive cellular structure of the villi it is almost certain that they proceed from the outer layer of the blastodermic vesicle, to which therefore must be mainly attributed the first origin of the chorion. These villi extend over a large portion of the surface, perhaps only excepting the embryonic area and a part of the ovum where it is not in contact with the uterine wall. They are at first destitute of blood-vessels and are of simple cellular structure. They soon become pervaded in their interior by connective fibro-nuclear tissue derived from the mesoblast, which extends itself below the primitive epiblast. Some time later or after the development of the vascular membranes of the yolk and allantois, and after the completion of the fold of the amnion and the separation of the false amnion, the villi acquire blood-vessels which penetrate the connective tissue of their interior, and are in some animals wholly, in others partially derived from those of the allantois; in the latter case, as before stated, the chorion receives blood-vessels also from the yolk-sac.

In birds the separation of the parietal and visceral mesoblast, and the intervention of the allantois between them, leads to the formation of an external membrane, composed of epiblast and parietal mesoblast, which lies close to the outer covering of the egg; but this membrane afterwards unites with the visceral mesoblastic layer of the allantois and thus loses its independence.

In mammals, however, this external membrane formed of the false amnion and its peripheral continuation in the blastodermic vesicle constitutes the basis of the chorion, and is the same as that to which Turner proposes to give the name of *subzonal membrane*.

The further history of the development of the chorion will be given in connection with the formation and structure of the placenta, but previously to entering upon that subject, it will be proper at this place to give some account of the early development of the human ovum and embryo.

HUMAN UTEROGESTATION.

1. **Early Stages of the Human Ovum.**—Great obstacles have stood in the way of the study of the earlier stages of the development of the human embryo and its membranes from the extreme rarity of the opportunities for observing the ovum in perfectly natural conditions within the uterus after death, and from the frequency of abnormal changes in aborted products in the first two months of pregnancy. Within the last few years, however, some important contributions have been made to the knowledge of this subject, among which is deserving of special notice the elaborate Monograph, by Professor His, in which much new information is supplied and the first systematic attempt has been made to investigate the human embryo by the method of sections (No. 132, 1880–82).

The impregnated ovum has never been detected in the course of its descent through the Fallopian tubes of the human female. From the analogy of animals and some observations on the changes in the uterus it is believed that the human ovum may arrive in that cavity at the seventh or eighth day after impregnation, but although instances are recorded in which at the eighth day a delicate vesicular body was found partially imbedded in the inner wall of the uterus, which from the probability of impregnation having taken place might possibly be an ovum, yet these bodies were not observed with sufficient accuracy to determine their nature, and it does not appear that the human ovum has been with certainty distinguished in the uterus before the tenth or twelfth day.

In a certain number of such observations the ova were found to have attained the size of a small pea or nearly a quarter of an inch in diameter, and were already more or less beset with villi on the outer surface of the chorion: no embryo was to be seen in these cases, nor such a structure of the membranes as to make it probable that the process of embryonic development had made any advance.

Fig. 663.

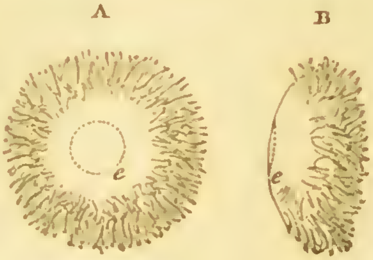


Fig. 663.—Front and side views of an early human ovum four times the natural size (from Reichert).

This ovum is supposed to be of thirteen days after impregnation. The surface bare of villi is that next the wall of the uterus, showing at *e*, the opacity produced by the thickened embryonic disc. The villi covered chiefly the marginal parts of the surface.

One case of this kind deserves especial notice from the very favourable circumstances under which it was examined (Reichert, 1873, No. 125). It was found in the uterus of a woman who committed suicide, and from the facts known as to her history it was believed by Reichert to be of twelve or thirteen days after conception. Its largest diameter was 5·5 mm. Its shape was that of a flattened spheroid, and the simple villi which partially beset its surface extended mainly over the equatorial margins, and left the two flatter surfaces bare to the extent of 2·5 mm., or $\frac{1}{10}$th of an inch. No traces were anywhere to be detected of an embryo; but the membrane of the ovum from which the villosities sprang was of cellular structure, and in the middle of the smooth part, turned towards the uterus, there was an opaque spot which might be taken for an embryonic area, and which presented internally a thin layer of finely granular nucleated cells. The ovum lay on the inside of the posterior surface of the uterus near the upper border, imbedded in the thickened mucous membrane or decidua, and having a thin covering of the same substance, which with the included ovum formed a rounded projection into the cavity of the uterus.

It may be doubtful how far the process of development had advanced in this ovum, but supposing Reichert to be correct in holding that no parts of the embryo had yet been formed, it would appear that in the human embryo villi may be developed from the blastoderm, as occurs in some animals, previous to the formation of a reflected amnion.

Fig. 664.

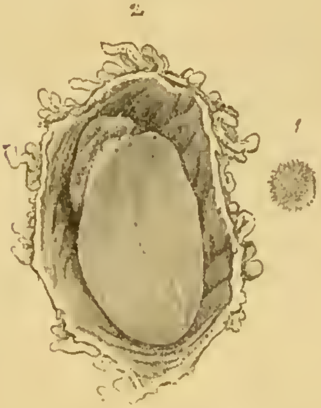


Fig. 665.

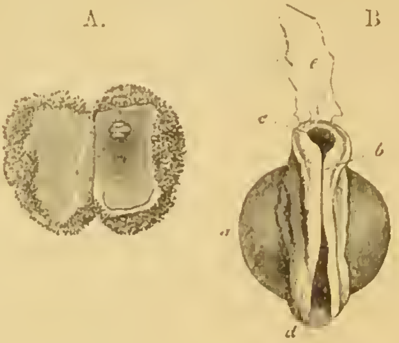


Fig. 664.—Human ovum of 12 to 13 days (from Allen Thomson).

1. The ovum of the natural size with simply villous chorion.
2. The same opened and magnified seven times. The large yolk-sac is seen with the embryo seen sidewise lying flat upon the yolk-sac.

Fig. 665.—Human ovum and Embryo of about 14 days (from Allen Thomson).

A. The ovum opened, half the chorion laid to one side and the embryo and yolk-sac seen in the other; natural size.

B. The embryo and yolk-sac viewed from the dorsal aspect, magnified about ten times; *a*, yolk-sac; *b*, hind brain portion; here for a space the medullary canal is closed; *c*, the mid-brain open superiorly; *d*, hinder part of the medullary canal also open; *e*, portion of membrane, perhaps belonging to the torn amnion.

A somewhat similar case was observed by T. Wharton Jones (No. 118), in which also the side next the uterus was devoid of villi and there was no appearance of an embryo. Another instance observed by Breuss presented nearly the same phenomena. (No. 126).

The first appearance of the human embryo as a primitive trace, or with a simple medullary groove, has not been observed. Among the earliest human ova in which features of embryonic structure are distinctly recognisable are two first described by the writer of this section in 1839 (No. 119), and another described by His (No. 132), which may have been even of a slightly earlier date.

In this stage the embryo, which consists almost entirely of its primary axial parts, lies prone on the surface of the yolk-sac, after the manner of a chick on the second day or the rabbit on the tenth. The heart exists, and doubtless a vascular area on the surface of the yolk-sac, though not fully observed, was already the seat of the first circulation. From the researches of His it seems probable that in the two first mentioned specimens, the amnion, although imperfectly observed nevertheless already existed, but had been accidentally destroyed, and His is of opinion that in these and other similar cases the allantois, which in the human ovum is undoubtedly formed at a very early period, had already grown out from the hinder part of the body of the embryo so as to become attached to the interior of the chorion, as illustrated by the accompanying diagram. (Fig. 670.)

Fig. 666.

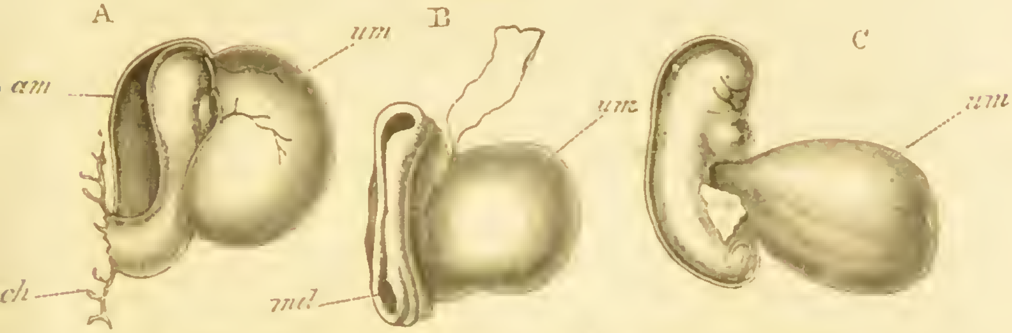


Fig. 666.—Three early human embryos (from Balfour after His).

A. An embryo of less than fourteen days, described by His. *am*, amnion ; *um*, umbilical vesicle ; *ch*, chorion to which the embryo is attached by a stalk.

B. Embryo of about fourteen days, described by Allen Thomson. *um*, umbilical vesicle ; *md*, medullary groove.

C. Embryo of sixteen or eighteen days, described by His. *um*, umbilical vesicle.

Fig. 667.

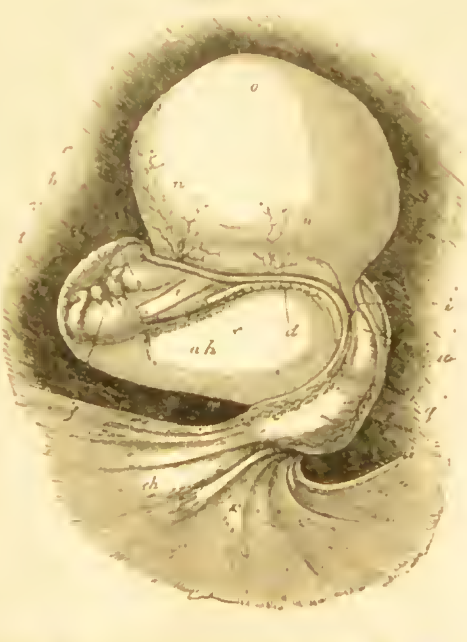


Fig. 667.—Human embryo of 15—18 days, with yolk-sac, amnion and umbilical pedicle. Magnified (from Kolliker after Coste).

b, aortic bulb ; *c*, heart ; *d*, margin of the wide abdominal opening ; *e*, œsophagus ; *f*, branchial arches ; *i*, hind-gut ; *n*, *m*, vitelline vessels ; *o*, yolk-sac, its vessels not fully represented ; *u*, stalk of allantois ; *a*, allantois with distinct vessels forming a short umbilical cord united to chorion ; *v*, amnion ; *ah*, its cavity ; *ch*, chorion.

Somewhat more advanced than the foregoing is the ovum well described by Coste (No. 22, iii.), which was probably of from fifteen to eighteen days, and of which the whole diameter was 13 mm., or fully half an inch. The embryo, of 4·4 mm. in length, lay upon a vitelline sack at one side of the cavity within the chorion, and was there fixed by an umbilical cord to the interior of that membrane, while a distinct amnion enveloped its other side. The parts of the heart with the pericardium were distinctly recognisable, as well as several other points of structure belonging to the embryo, which will be referred to at a later period. The cephalic portion of the intestine was formed and enclosed, but the larger hinder part was no more than a groove opening widely into the yolk-sac (fig. 667). The vitelline vessels were distinct on this last. The chorion was uniformly covered with villi, which were hollow; and the vascular layer of the allantois ran inside it without however yet penetrating the villi.

An embryo described by His, marked L in his Monograph, presents some of the same features. (Fig. 666, A.)

In human ova which may be estimated as approaching the term of three weeks after conception, the body of the embryo is found to be curved, the cephalic flexure has also taken place, several of the pharyngeal bars and clefts appear below the cranium, and the communication between the intestine and yolk-sac is much reduced in size, though still wide.

Fig. 668.

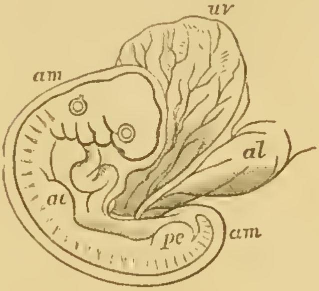


Fig. 669.

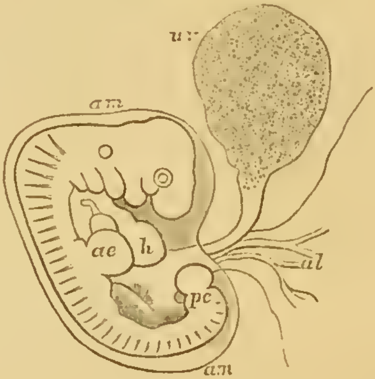


Fig. 668.—Outline of human embryo of about three weeks. $\frac{5}{1}$ (A.T.)

Fig. 669.—Outline of human embryo of about four weeks. $\frac{4}{1}$ (A.T.)

am, amnion; *uv*, yolk-sac; *al*, allantoid pedicle; *ac*, anterior extremity; *pc*, posterior extremity; *h*, heart.

In the next stage, of which the age may be reckoned as of fully three weeks (see fig. 668), the extremities begin to appear as semi-circular plates projecting from the lateral ridge of the body. The Wolffian bodies are formed, the visceral arches are now four in number, including that of the lower jaw, with the clefts between them, the intestine has become tubular and the vitello-intestinal communication is diminished in width. At four weeks (fig. 669) these features are more pronounced, the yolk-sac is pyriform, its duct is thin and elongated, and the extremities begin to divide into proximal and middle segments.

In the earliest stage at which the human embryo has been observed, or near the end of the second week, the symmetrical rudiments of the body lie prone upon the surface of the yolk-sac enclosed in an amnion and with an allantoid adhesion to the chorion. In the course of the third week, the midgut becoming more and more tubular, the head and trunk of the embryo undergoing incurvation, and the abdominal walls converging ventrally, the umbilical aperture, which is at first very wide, contracts and embraces more closely the diminishing vitelline duct and the allantoid vessels; and by the sixth week the amnion, which was at first very close to the body of the embryo, is separated from it by the increase of the amniotic fluid, and the umbilical attachment begins to elongate into a cord over which the amnion is inflected.

Up to this time the human embryo presents a remarkable resemblance to that of most mammals, and also to some extent of birds and reptiles of a corresponding stage of development; but in the period which follows, or from the sixth to the eighth and still more to the tenth weeks, the changes which it undergoes, though agreeing in their general nature with those which take place in other animals, are so modified as gradually to bring out the peculiar features which are characteristic of the human form and type of organisation. Among these the most marked are the large and early development of the cerebral hemispheres which gives peculiar prominence to the forehead and upper part of the head, together with the comparative small size of the maxillary and mandibular parts of the face, the form of the external auricle, and the form and attitude of the limbs.

Fig. 670.

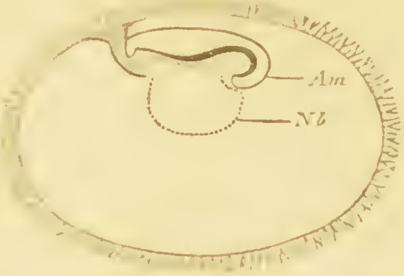


Fig. 670.—Diagrammatic section of the early human ovum according to His. (From Balfour after His).

Am, amnion; *Nb*, umbilical vesicle.

It would have been desirable to give some account at this place of the rate of progress and the peculiarities of form and structure belonging to the successive stages of early growth and development in the human embryo; but the want of space and the paucity of materials for such an account as would be satisfactory forbid the attempt for the present, and oblige us to refer the reader to the useful plates of Erdl (No. 23), and to the important contribution to the subject made by His in the second part of his work on the human embryo (No. 132).

Returning to the subject of human uterogestation it is to be observed that the mode in which the connection of the embryo with the chorion is established by the allantoid pedicle and vessels, as well as the early condition of the amnion, present some peculiarities of which direct observations have not yet furnished a full explanation, or one which would bring the phenomena into conformity with the modes of development of the membranes hitherto most familiar to embryologists. But several recent observations seem to show that important deviations from the better known types of development among mammals may still be discovered by future investigations.

Fig. 671.

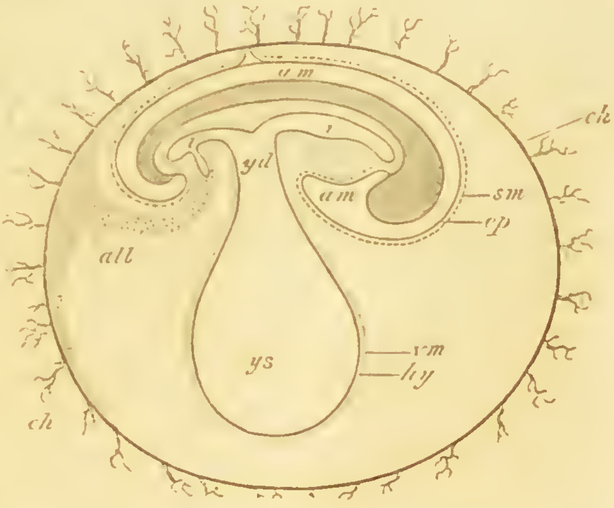


Fig. 671.—Diagrammatic outline of section of human ovum at three weeks (A. T.)

ch, chorion; *ep*, epiblast of reflected amnion; *sm*, parietal mesoblast; *am*, amnion; *ys*, yolk-sac; *all*, allantois; *vm*, visceral mesoblast (vascular layer); *hy*, hypoblast.

The view taken by His (No. 132. I.) that the outer layer of the human allantois is from a very early period in close proximity to, if not in actual union with the primitive chorion, would not be inconsistent with what is already known of the development of the membranes in most animals, if it could be supposed, as seems necessary, that the mesoblast of the allantois extends itself in the intermesoblastic space, and is therefore at first within a caudal or equivalent fold of the amnion. It is difficult indeed to conceive how the vascular layer of the allantois could pass round the whole interior of the chorion, except in a space formed between the outer and inner folds of the amnion.

Schäfer's observations in the guinea pig (No. 100. ii.) and Fraser's in the Rodentia, sufficiently show how early the vascular layer of the allantois may extend itself towards the chorion in some tribes of animals, and the researches of His on early human ova, as well as those of Coste and others go far to prove the early union in a peculiar manner of the outer layer of this membrane with the chorion.

2. **Enclosure of the Ovum in the Uterine Decidua.**—It is now well known that the uterus is prepared for the advent of the ovum by the increased development of certain parts of its mucous membrane which give rise to the decidua.

A similar change takes place previous to every menstrual period, but in case of pregnancy occurring there is no exfoliation of the membrane such as follows in menstruation, but on the contrary the development of the decidual elements of the mucous membrane progresses to a much greater degree. These changes are probably of two kinds, the first consisting mainly in the increase of the subepithelial cellular elements of the mucous membrane, together with a dilatation and subsequent atrophy of parts of the utricular glands, and the other in a great enlargement and change of structure of the uterine blood-vessels, which together prepare the way for the formation of the maternal part of the placenta in the more limited area occupied by that structure.

Embryologists were for long at a loss to understand how the human ovum, which enters the cavity of the uterus quite free from any reduplication of the uterine lining membrane, becomes very soon completely enclosed, or *incapsulated* in its substance. Nor have the actual steps of the incapsulation ever yet been directly observed. But the fuller knowledge of the nature of the change which the lining membrane of the uterus undergoes before and after the arrival of the ovum in its cavity, and the closer observation of the nature and relations of the material by which the ovum is enclosed make it extremely probable that, as was first suggested by Sharpey (No. 15, iii., p. 1580), the minute ovum, on entering the uterine cavity, and possibly being sunk in one of the depressions which lie between the bulging areas of hypertrophied mucous membrane, is gradually surrounded by a wall of the decidual substance, which rising from below encroaches more and more upon the surface of the ovum, and comes at last to cover it entirely and to exclude it from the uterine cavity.

When the ovum has been fully imbedded in the decidua, as at the third or fourth week, it forms along with the decidua a swelling or projection within the uterine cavity, on opening which the villous chorion is found everywhere surrounded by the substance of the decidua; but the part of the latter substance which passes over the free surface of the ovum, or that which is towards the uterine cavity, is thinner and simpler in its structure than at the place of attachment of the ovum and in other parts of the uterine surface; and its appearance at the most projecting part or summit, different from the rest, indicates, by a sort of cicatricial mark, the place where the substance of the decidua, as it gradually covered in the ovum, may be supposed to have finally closed.

The decidual thickening of the mucous membrane affects nearly equally the whole of the lining of the uterine cavity, but towards the os internum, and across the fundus to the Fallopian tubes, the thickening, first suddenly and then gradually, decreases, and the membrane assumes the unaltered condition which is maintained in these passages.

By the changes now described there has become apparent the distinction of the three portions of decidua usually recognised by authors, viz., *decidua vera*, *reflexa*, and *serotina*. The first of these is that portion of the altered membrane which lines the general cavity of the uterus in

Fig. 672.

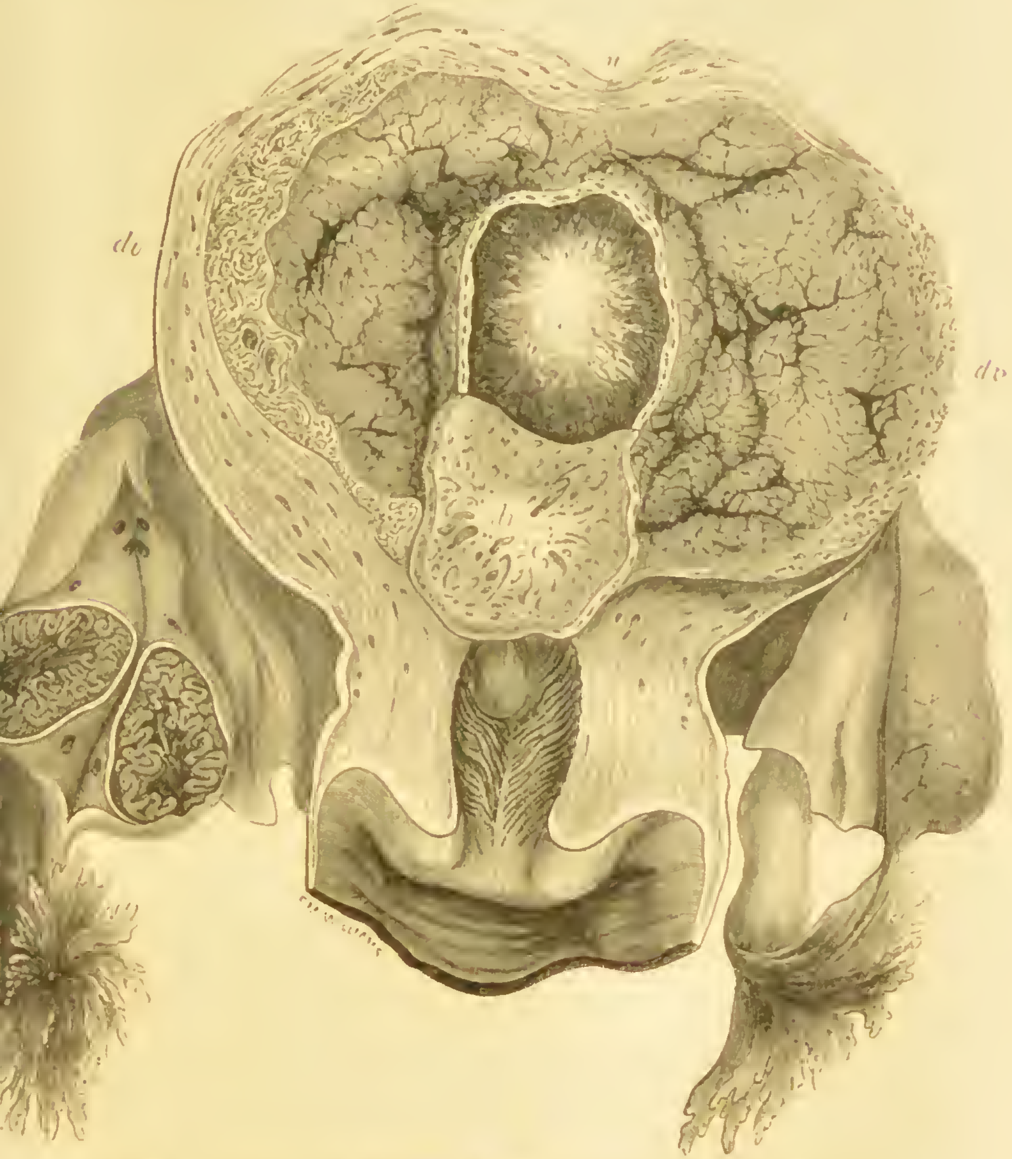


Fig. 672.—View of the interior of the human gravid uterus at the twenty-fifth day (from Farre after Coste).

u, uterine wall; *o*, villi of the chorion of the ovum; *dv*, decidua vera and enlarged uterine glands; *dr*, decidua reflexa, divided round the margin of the ovum, and turned down so as to expose its pitted surface, which has been removed from the ovum. The right ovary is divided, and shows in section the plicated condition of the early corpus luteum.

every part except that occupied by the attachment of the ovum; the decidua reflexa is that which covers the ovum as it projects into the uterine cavity, and which is continuous with the decidua vera round the base of the swelling. The name of *decidua serotina* (or late formed) is most frequently employed to denote the layer or layers of decidual substance which intervene between the developed placenta and the uterine wall outside it; but by some it has been made to include also the part of this structure which originally enters into the formation of the maternal part of the placenta, thus including a placental and a uterine decidua serotina.

Fig. 673.

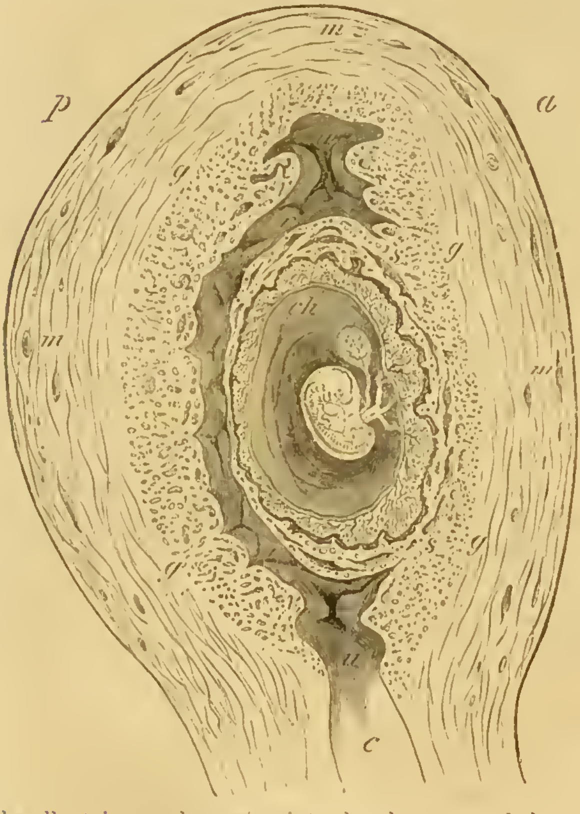


Fig. 673. — SEMI-DIAGRAMMATIC OUTLINE OF AN ANTERO-POSTERIOR SECTION OF THE GRAVID UTERUS AND OVUM OF FIVE WEEKS (A.T.).

This drawing is taken from a very perfect specimen of the uterus obtained from the body of a woman who died of cholera in 1849.

a, anterior uterine wall inside which was situated the placental attachment of the ovum; *p*, posterior uterine wall (the accessory parts being omitted); *m*, muscular substance of the wall; *v*, thickened lining membrane forming decidua vera, and showing grooves and eminences on its surface and enlarged glands and vessels in its substance; *g*, the glandular or deep layer; *r*, the decidua reflexa; *u*, indicates the uterine cavity; *s*, decidua serotina; *c*, cavity of the cervix uteri; *ch*, chorion with its villi, which are more highly developed on the placental side; *e*, the embryo enclosed in the amnion, with the allantoic vessels passing into the placenta, and the umbilical vesicle.

The blood-vessels and the glands of the mucous membrane also undergo great enlargement and modification. The whole of the decidua vera and the adjoining part of the reflexa are at first penetrated by blood-vessels derived from those of the uterus, more especially in the latter part of the second month, when the decidual structure may be considered as having reached its highest degree of development. After this time the blood-vessels of the decidua reflexa, and later those of the whole lining decidua of the uterus, except in the immediate vicinity of the placenta, shrink and ultimately disappear, so that the membrane formed by the united deciduæ becomes in the end wholly non-vascular. The same retrograde process, leading to atrophy and disappearance, occurs in the blood-vessels of the chorionic villi by which the decidua reflexa is penetrated, and, although the villi themselves never entirely disappear, but may be traced even in the advanced stages of pregnancy as sparse and shrivelled irregular arborescent processes, the blood-vessels very soon begin to shrink and disappear from all the villi which do not form part of the placental structure. To the changes occurring in the decidua serotina as connected with the placenta reference will be made further on.

The Placenta.—The general relations of the fœtal and maternal structures of the human placenta are illustrated in an interesting manner by the study of the different forms which they present in various orders of mammals, or as it is called of their *placentation*; but limitation of space prevents our entering upon any full account of this subject, and the reader is referred to the works of Turner (No. 150, ii.), Ercolani (No. 147, iv.), and other authors.

Fig. 674.

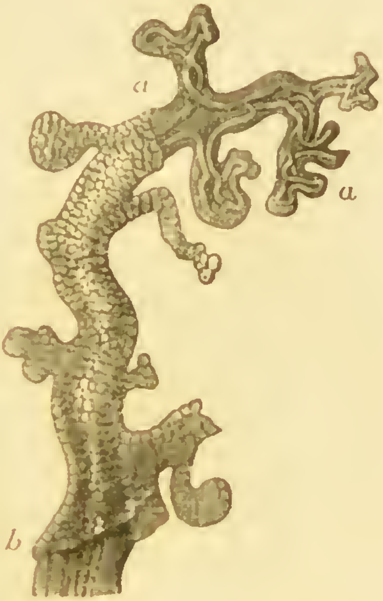


Fig. 674.—Chorionic villus from the placenta at the twelfth week. Enlarged 180 diameters (from Leishman after Ecker).

From *a* to *b*, the epithelial covering is left entire; from *a* to *a* it has been removed and the fibrous core with the capillary blood-vessels is shown.

The general result of recent researches on the Comparative Anatomy of the placenta may be thus stated. In all mammals, so far as is yet known, excepting the monotremata and marsupials, the true placental structures consist in the establishment of a close relation between finely ramified fœtal blood-vessels derived originally from the outer or mesoblastic layer of the allantois, with minutely or widely distributed blood-vessels belonging to the uterus. Both of these are originally at least, if not throughout the whole of gestation, accompanied and supported by cellular and other constituent elements of the fœtal and maternal structures to which the blood-vessels respectively belong; as, on the part of the fœtus, the villous ramifications of the chorion, and on the side of the mother a corresponding development of a part of the lining membrane of the uterus; while the uterine glands do not appear to take any direct or important part in this combination of fœtal and maternal elements.

a. Early Development of the Human Placenta.—The human placenta and that of the Apes are characterised, 1st, by the fact that the chorion derives its blood-vessels exclusively from the allantois, which are ramified in the villi to a very great extent and degree of minuteness, and, 2nd, by the enormous dilatation of the uterine vessels, and the very marked changes undergone by the decidual or perivascular tissue, which give rise to a structure different from that of any other animal.

All are now nearly agreed on general grounds that some combination of fœtal and maternal parts occurs in the formation of the placenta; but we are still far from having an exact knowledge of the manner in which the union is effected. Sufficient observations are in fact wanting to show in a series the successive conditions of the placenta during the period of most active change, *i.e.*, from the 5th or 6th week up to the

the dilated cavities of the uterine glands, but are sunk in crypts of the decidua which lie between the glandular orifices. Nor is there any reason to believe that the villi enter the uterine glands in the formation of the human placenta. On the contrary, the observations of Schröder van der Kolk, Kölliker, Turner and others are quite opposed to such a view.

b. Structure of the Advanced Human Placenta.—After the middle of pregnancy, the placenta forms a large discoid or lenticular mass, of from four to five inches in its larger diameter and about three-quarters of an inch in thickness, interposed in a limited space between the fœtal membranes and the uterus. It presents a fœtal and a uterine surface, the former having implanted into it, usually near the middle, the umbilical cord, containing the allantoic or umbilical vessels, and covered by a tubular prolongation of the amnion. The placenta continues to increase in size with the fœtus, and when it has attained its full dimensions, it has a width of from seven to eight inches, or even more, and a thickness of about one inch and a quarter. Towards the circumference it rapidly thins, where it becomes continuous with the chorion and decidua. The fœtal surface is

Fig. 676.

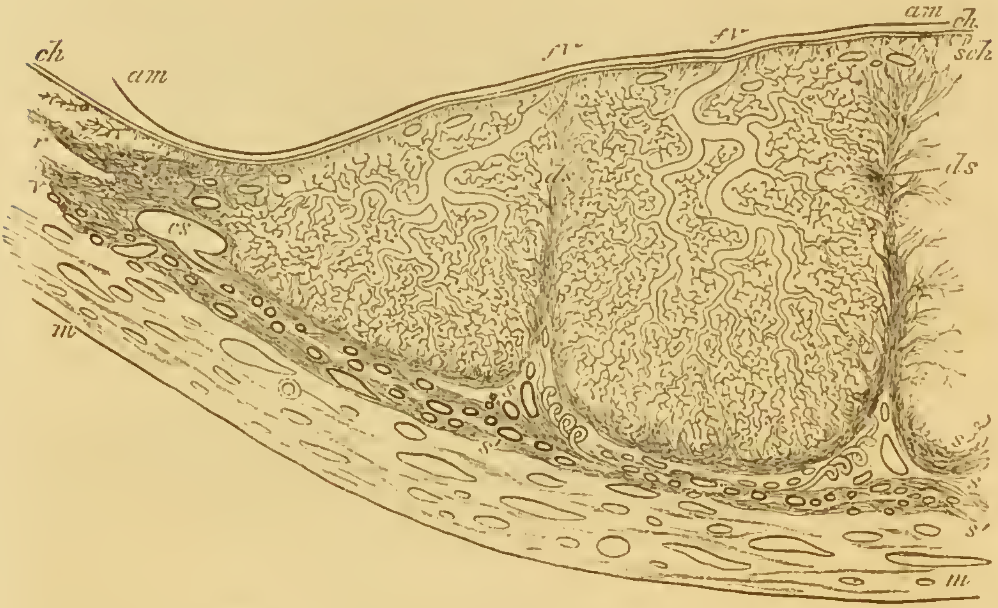


Fig. 676.—Diagrammatic representation of a section of the human placenta near the margin at five or six months (slightly enlarged). (A.T.)

am, amnion ; *ch*, chorion ; *fr*, stems of fœtal vessels passing into two of the placental lobes in the villi of which they undergo capillary ramification ; *m*, muscular wall of the uterus with divided arteries and veins ; *v*, decidua vera ; *r*, d. reflexa ; *s*, decidua serotina placentalis ; *s'*, d. serotina uterina ; *ds*, septa of decidua passing from the serotina between the lobes, branching into their interior, and reaching the chorion ; in their bases are seen the maternal coiled arteries and the divided veins ; *cs*, circular sinus ; *sch*, the subchorionic decidual layer. An attempt is made in this diagram to show the union between the penetrating processes of reticulated decidua serotina and the villi of the lobes, the union extending in this, which is a marginal part of the placenta, as far as the subchorionic layer of the decidua.

covered by the chorion and amnion, and is traversed by the larger divisions of the umbilical vessels before they dip into the substance. The uterine surface shows a subdivision into a number of large lobes, sometimes called cotyledons, which are covered with a layer of decidua serotina passing over the whole of this surface, and sending septal prolongations into the placenta between the lobes, which may be traced in some places as far as the fœtal surface.

The more uniform parenchyma of the placenta within these lobes, which to the naked eye presents the appearance of a minutely divided sponge, consists in greatest part of highly-developed and complicated tufts of fœtal villi which adhere to the chorion by vascular stems of considerable size and strength, and subdivide again and again into minute and complex ramifications. Between the innumerable subdivisions of these tufts are the irregular vascular spaces or lacunæ, the outlines of which follow closely the ramifications of the villi throughout every inflection of their surface. These spaces, which are filled with the maternal blood and are continuous with the uterine vessels, are doubtless to be regarded as belonging to the maternal system, but their minute structure and anatomical relations have been so greatly modified in the progress of the placental growth, that, as already stated, it has been found very difficult to determine their exact nature in the fully formed condition.

On its outer side the placenta is united to the uterine wall by the decidua serotina, consisting, as already mentioned, of two layers, of which the inner alone enters directly into the formation of the placenta. From this inner layer of the serotina septa are prolonged between and surround more or less completely the lobes, so as to separate them from one another with very obvious but interrupted bands of decidual tissue; and from these interlobular septa irregular branched processes run into the interior of the lobes and through the placenta, so as even to reach the chorion in many places, and to unite with the subchorionic layer of decidua which extends from the margin of the placenta upon the chorion for a considerable distance, if not over its whole placental surface; and it thus becomes apparent that both fœtal and maternal (or decidual) structures are intimately intermixed throughout the whole thickness of the placenta.

A minuter examination of the spongy or finely divided portions of the placental lobes shows that in these the innumerable terminal villi of the branched fœtal placental tufts lie or hang for the most part free in irregular spaces (intervillous lacunæ) filled with the maternal blood; but they are not entirely loose, for, beside the stalks on which they are set, in numerous places they are attached at their tips and also on their sides by slender bands and sometimes finer filaments of very irregular form and of a granular fibro-nuclear substance, which pass from one to another of the villi, and between them and the processes of the decidua serotina, and which seem to be composed of decidual elements; forming thus according to Turner a network of trabeculæ derived from the decidua serotina in the interspaces of which the villi are contained (150, iii.).

The maternal blood spaces present the most varied and irregular forms, which scarcely admit of description, and, as they all intercommunicate freely, may rather be compared to a labyrinth, the walls of which are entirely formed by the villi over which they are moulded; so that it is obvious that the villi, with whatever covering they may possess, are in full contact with the maternal blood which permeates all the intervillous spaces or lacunæ.

The fœtal villi present from a very early period, and long before they have entered into any combination with the uterine structures, a distinct external covering of epithelium which may be called chorionic, and as soon as they become vascular their interior is occupied by a core of connective tissue in which the fine divisions of the allantoic vessels are imbedded. In the more advanced stages of placental growth an increase of the fœtal vessels corresponding with the prodigious ramification and extension of the villi takes place, and besides the deeper loops of capillary and other vessels which occupy the interior of the villi there is developed also a more superficial capillary network (Schröder van der Kolk, No. 141) ; but in other respects the individual or terminal villi do not appear on a superficial inspection to differ greatly from those of the earlier stages.

On the other hand, there is good reason for regarding the maternal blood-spaces of the advanced placenta as essentially enlarged and altered decidual blood-vessels ; for though the whole steps of the process of conversion have not been traced with sufficient fulness or accuracy, we are not without evidence from observation (Virchow, No. 142, and Priestley, No. 144) that the intervillous lacunæ must owe their origin to the disappearance of the decidual arteries and veins as such and the enormous dilatation of their capillaries around the villi, and to the thinning away of the decidual tissue in which they were previously distributed.

Microscopic observation has shown that the peculiar coiled vessels which pass through the serotina as the prolongations of the uterine arteries are destitute of the middle and outer arterial coats, but are lined with epithelium, and open directly by sudden enlargement, and without the intervention of any capillary vessels, into the wide cavities of the placental sinuses, and further that these sinuses are brought into direct communication with the larger uterine veins by means of considerable venous canals, lined with epithelium, which pass in a slanting manner through the decidua serotina, as well as by others which join the venous plexus named the circular sinus situated round the margin of the placenta.

Relation of the Fœtal and Maternal Elements in the fully-developed Placenta.—Such being the history of the fœtal vessels, and the maternal blood-spaces in the placenta, there still remain the important and difficult questions which have been long discussed, and which have not yet received a satisfactory solution—viz., What has become of the decidual tissue, and the maternal vascular lining in the developed placenta? Have they been entirely removed by atrophy and absorption, or are they still persistent, and are their remains still to be found as coverings of the villi, or in any other form?

As holding the first of these views Virchow, Kölliker, and Leopold may be quoted ; and as supporters of the second, Schröder van der Kolk, Ercolani, and Turner.

It would occupy too much space to attempt any review of the arguments adduced in favour of these opposite views ; and we must therefore refer the reader to the works of the authors quoted in connection with this subject, remarking at the same time, that while the greatest share of probability seems on general grounds to belong to the first view, or that of Kölliker, viz., that the villi retain their original epithelium, and that the maternal structure must have suffered atrophy and disappearance ; the other opinion is not without some evidence in its favour. And more especially if it could be shown, as Ercolani asserts—and in this he is supported by Romiti (No. 157)—that in the villi of the tenth week both the fœtal and maternal epithelium are still present together, while the fœtal or deeper epithelium appears to be undergoing atrophy preparatory to its removal. the view taken by that author. that in the formation of the placenta the decidual cells are substituted for the fœtal epithelial covering. and possibly also that a thin layer. representing the lining epithelium of the maternal vessels, overlays it externally on the surface of the villi. might receive important confirmation.

But. as before remarked, further researches are still required in the period of placental development. extending from the fifth or sixth week onwards into the third and fourth months. to enable us to determine the precise manner in which the peculiar condition of the maternal sinuses in the human species and in Simiæ is brought about. There can be little doubt that this condition is essentially different from that which has been well shown by the researches of Turner and Ercolani to prevail in other animals. in which it appears that. along with the fœtal capillary blood-vessels, and the epithelium of the villi. there are always present distinct maternal elements, in the form of capillary or other vessels lined with epithelium, and a certain amount of obvious decidual tissue surrounding them.

Relation of the Uterine Glands to the Placenta.—It has already been stated that the villi do not penetrate into the uterine glands of the human placenta. These glands undergo. it is true. in the earlier three months of uterogestation great enlargement and modification of their form. In the decidua vera especially the enlarged state of the glands is well known and very apparent in the early months of pregnancy ; but as the membrane thins out in the later months. they are much flattened and atrophied. but are not entirely lost. In the inner layer of the decidua serotina they very soon become obliterated and disappear. but in the outer or uterine layer their cavities remain in a much widened condition. though drawn out and flattened : and it seems as if they gave rise in part to the separation of the outer and inner layers. where the severance afterwards occurs in parturition. In the outer layer. however, the glands are preserved in such a state as to be capable of restoration after parturition in that part of the mucous membrane.

The outer layer of the serotina is also the principal seat of the development in the latter half of pregnancy of the largest or giant multinuclear cells. which are characteristic of that layer in man. as well as in many animals. In connection with these cells. it is proper to mention the important discovery made by Friedländer (No. 152), and confirmed by Leopold (No. 156). according to which it appears that the main veins of the serotina and the adjacent part of the uterine wall undergo in the later stage of pregnancy a process of gradual obliteration by the ingrowth of the giant cells into the interior of the veins—a process which begins in the eighth month. and goes on progressively up to the end of gestation. and which seems to have the effect of producing stagnation and stoppage of the passage of the blood through the veins. and may probably be a factor in the induction of the act of parturition.

Placental Circulation.—The existence of a distinct circulation of blood in the fœtal and in the maternal vessels of the placenta. discovered by the Hunters, has long been placed beyond doubt by the experimental investigations of all those who have injected the two sets of vessels with sufficient care and success. By artificial injections fluids can be made to pass from the umbilical arteries through the capillaries of the villi into the veins. or in the reverse direction from the veins into the arteries. Nor does there ever occur. except from ascertained accidental rupture of the vessels. either extravasation of the injected material into the intervening tissue, nor any escape into the maternal sinuses.

The result of artificial injection of the blood-vessels in the pregnant uterus equally demonstrates the nature of the circulation in the maternal part of the placenta. for it is easy to show by this method that a fluid thrown into the uterine arteries passes through the coiled vessels and fills all the maternal blood-spaces of the placenta. surrounding everywhere the chorionic or fœtal villi. and returns thence into the uterine veins by the slanting venous channels. the *utero-placental sinuses*. lined with epithelium. which issue from the placenta at its uterine surface by piercing the decidua serotina, and which are also very numerous towards the circumference of the organ, where they are in communication with the venous plexus or so-called circular sinus. Some of these veins may even be traced for some distance into the placenta, in the septa of decidual substance, which are prolonged from the decidua serotina between the lobes. (See Turner, Kölliker, and others).

Separation at Birth and Restoration of the Uterine Membrane.—In the act of birth a large part of the decidual structures which have been formed in human uterogestation, including that which is strictly placental, the whole of what remains of the d. reflexa and a considerable part of the d. vera, now fused into one thin covering of the chorion, are separated from the uterus, together with the fœtal placenta, the membranes, and all that belongs to the ovum. Thus in parturition, by the effect of uterine contraction, the fœtus is first expelled; the detached placenta follows, and carries with it the inner layer of serotina, the coiled arteries and the slanting veins being broken through; next come the inverted membranes of the ovum, together with the remains of decidua reflexa and part of the vera, which are finally peeled off the whole of the interior of the uterus. On the uterine surface a part of the decidua vera remains, and also the uterine decidua serotina lying next the muscular wall of the uterus. In this layer are imbedded the remains of the convoluted uterine glands, which extend outwards into the substance of the muscularis mucosæ. These are soon prolonged to the uterine cavity, a ciliated epithelial lining is formed on the inner surface, and the natural structure of the whole membrane is thus completely restored.

II. DEVELOPMENT OF THE SYSTEMS AND ORGANS OF THE EMBRYO.

It will be convenient to treat of this, which is the most extensive division of our subject, under the following sections, viz.:—1. The External Form and Framework of the Body; 2. The Nervous System; 3. The Vascular System; 4. The Alimentary Canal and Associated Organs; 5. The Urinary and Generative Organs.

I. EXTERNAL FRAMEWORK AND WALLS OF THE BODY; THE SKELETON, VOLUNTARY MUSCLES AND INTEGUMENTS.

In the most general morphological view of the development of the external frame-work of the body, its parts may be regarded as being moulded in certain definite relations according to the vertebrate type upon the cerebro-spinal nervous centre and its containing cranio-vertebral cavity, and in their commencement they present the form of body-segments or somites, which in the trunk correspond in number with the vertebræ, but in the head follow a somewhat different arrangement. It will be convenient to begin with a short statement of the earliest phenomena of the development of the embryonic axis.

I. FIRST RUDIMENTS OF THE EMBRYO.

These consist mainly of four parts which, named in the order of their commencement, are the primitive streak, the medullary canal, the notochord, and the protovertebral somites. The first of these is essentially a temporary and evanescent structure; the third, round which the column of vertebral bodies is formed, though also transitory, is somewhat more persistent than the first; the second and fourth, as the foundation of important organs, may be regarded as permanent.

1. **The Primitive Streak or Trace.**—The earliest indication of the formation of the embryo is in the *primitive streak* which appears about the twelfth hour of incubation in the chick, and on the seventh day in the ovum of the rabbit, in that part of the embryonic area which, with reference to the position of the embryo, may be called the hinder, and which also is the narrower part when the area has become pyriform. It has not at first a linear or elongated form, but begins as a comparatively short sickle-like thickening of the blastoderm at the margin of the embryonic area, and subsequently stretches inwards upon the area, in the form of a narrow strap-like opacity, as previously described at p. 718. It is closely connected with the epiblast or upper layer, and its formation seems to consist more immediately in a proliferation of cells from the lower surface of that layer which results in the development of the mesoblast or middle layer through the whole length of the primitive streak, in which the epiblast and mesoblast are thus rendered continuous.

Fig. 677.

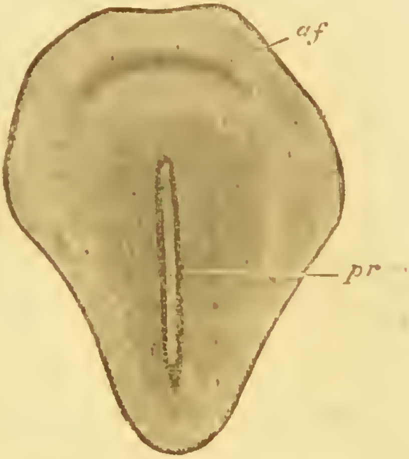


Fig. 677.—Pyriform transparent area of the chick's blastoderm with the primitive groove.

pr, primitive streak and groove ; *af*, amniotic fold commencing ; the darker shading round the primitive streak indicates the extension of the mesoblast.

In the course of its formation the primitive streak acquires a groove, the *primitive groove*, which arises from a depression in the epiblast at its upper surface. This groove does not usually extend to either end of the streak, but presents near its anterior extremity most frequently, but elsewhere also and somewhat variably in birds one or more depressions which are found to run through the blastoderm and indicate an interesting relation of the streak to the blastopore and neurenteric communication previously referred to (p. 759). The hypoblast takes no share in the production of the primitive streak, but runs across the area free and flat beneath it.

Fig. 678.

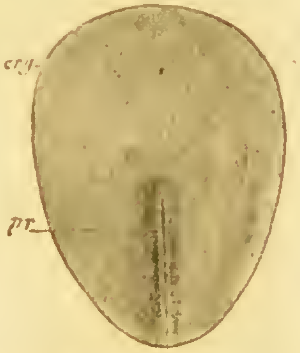


Fig. 678.—Embryonic area from the ovum of a rabbit of eight days. $\frac{23}{1}$ (From Kolliker.)

arg, border of the embryonic area ; *pr*, primitive streak with groove.

The primitive streak and groove were at one time confounded with the commencement of the true cerebro-spinal axis ; but it was shown by the observations of Dursy in 1867 (No. 90), and has been fully proved by His (No. 29, i.) and others following him, that it does not give rise to any part of the nervous centre nor to any other important organ, but on the contrary, is in a great measure transitory and evanescent in its nature; for though at first it indicates truly the direction of the embryonic axis, we shall find that it is thrust more and more backwards by the medullary and vertebral rudiments as they progressively grow in front of it, and it seems at last to be lost in the tissue below the caudal extremity of the embryo. Its real significance therefore lies mainly in its relation to the origin and connection of the layers of the blastoderm and their apparent invagination at a period preceding the first development of the cerebro-spinal nervous axis of the embryo.

Fig. 679.

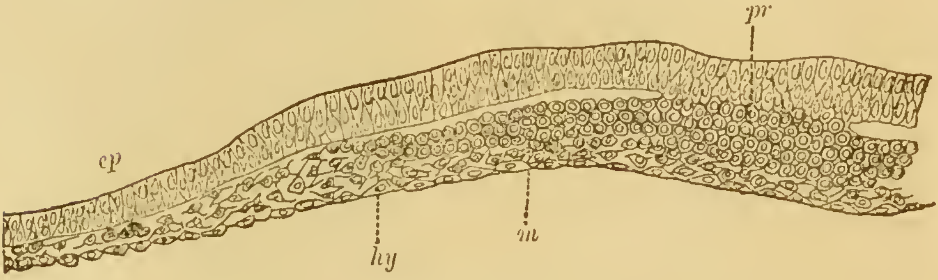


Fig. 679.—Transverse section through the front end of the primitive streak of the chick of about 12 hours. (From Balfour.)

pr, primitive groove; *m*, mesoblast; *ep*, epiblast; *hy*, hypoblast.

Fig. 680.

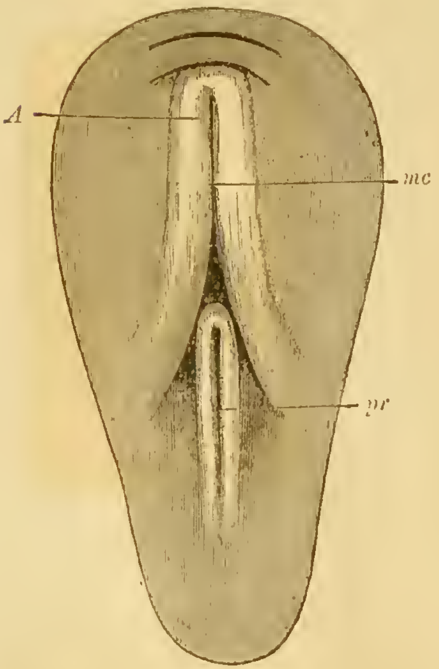


Fig. 680.—Surface view of the transparent area of a blastoderm of 18 hours, somewhat diagrammatic. (From Balfour.)

pr, primitive groove, closed in front by the coalescence of the two lateral ridges; *mc*, medullary groove, having on each side the medullary folds or ridges, *A*, which also meet in front to enclose the groove, but diverge behind so as to enclose the primitive streak; in front the fold of the amnion is commencibg.

2. **Medullary or Neural Centre.**—The first rudiment of the great neural centre makes its appearance somewhat later than the primitive streak, viz., in the chick about the eighteenth hour, and in the rabbit's ovum on the seventh day. It takes place entirely within the epiblast or outer layer, and depends on the growth of the cells of that layer in the anterior part of the embryonic area where it extends in the same direction as the primitive streak so as to occupy that part of the area left vacant by the latter.

The medullary plates which result from the thickening of the epiblast are at first comparatively short, corresponding mainly to that which will ultimately become the cephalic part of the nervous centre. They soon, however, elongate, and increasing in their thickness at the outer margins, they rise into lateral ridges, which are separated by a groove or furrow, while they run into one another, or are joined together round the cephalic extremity of the groove. Behind they diverge somewhat, and there they extend for some distance on either side of the primitive streak, so as to enclose nearly its anterior half between them.

Fig. 681.

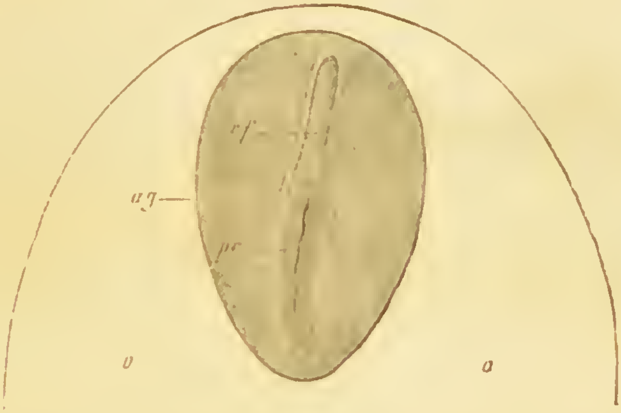


Fig. 681.—EMBRYONIC AREA, WITH OUTLINE OF THE VASCULAR AREA, FROM A RABBIT'S OVUM OF SEVEN DAYS. $\frac{23}{1}$ (From Kölliker.)

oo, vascular area; *ag*, embryonic area; *pr*, primitive streak and groove; *rf*, medullary groove.

Fig. 682.

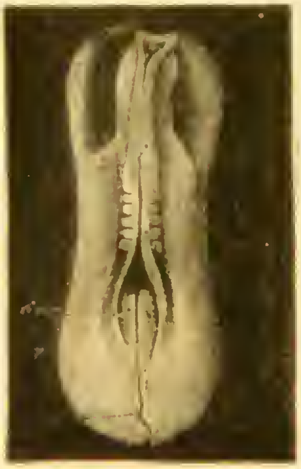


Fig. 682.—DORSAL VIEW OF A BLASTODERM AND EMBRYO CHICK HAVING FIVE MESOBLASTIC SOMITES. (From Balfour.)

a.pr, anterior part of the primitive streak; *p.pr*, posterior part; the medullary ridges have come together in the greater part of their extent, but have not yet united; the caudal swellings are visible on each side of *a.pr*.

As the formation of the medullary plates and groove progresses, they extend more and more backwards, so that the addition of new substance in the primitive or axial embryo takes place mainly by interposition between the part already formed and the primitive streak. As they extend backwards the ridges also rise more dorsally so as to deepen the groove, the cephalic part widens out into a somewhat conical hollow, while the spinal part remains of a more equable and smaller diameter.

In the next stage, which is completed by the 30th or 35th hour in the chick, and the 9th day in the rabbit, the medullary ridges of the epiblast bending round dorsally have met in the middle line above the medullary groove, and there coalesce, at first in a limited space near the middle, and later both forwards and backwards, so as to effect the union along the whole dorsal line, except at the hinder incomplete part. By this union the medullary plates and groove are converted into the neural or medullary tube, which constitutes the primary form of the brain and spinal marrow.

Fig. 683.

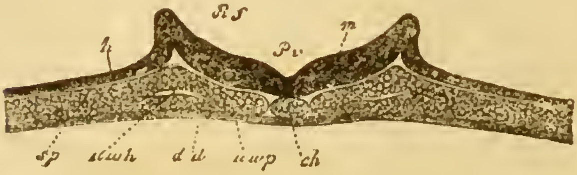


Fig. 683.—Transverse section through the embryo of the chick and blastoderm at the end of the first day. Magnified from 90 to 100 times. (From Kölliker.)

h, epiblast; *dd*, hypoblast; *sp*, mesoblast; *Pv*, medullary groove; *m*, medullary plates; *ch*, chorda dorsalis; *uwp*, proto-vertebral plate; *uwh*, commencement of division of mesoblast into its upper and lower laminæ; between *Rf* and *h* are the dorsal laminæ or ridges which by their approximation close in the medullary canal.

Fig. 684.

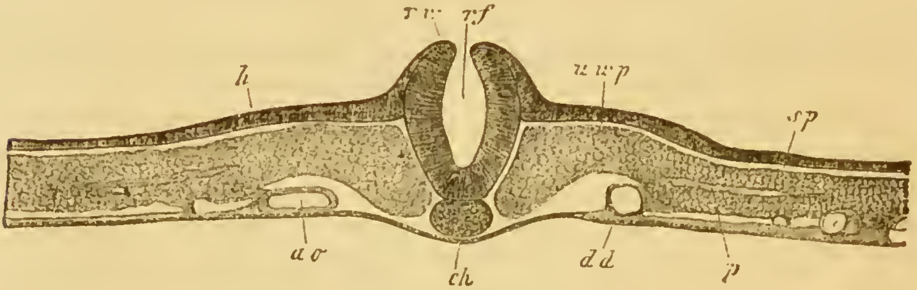


Fig. 684.—Transverse section of an embryo chick in the latter half of the second day, at the place where the vertebral somites cease. $\frac{80}{1}$ (From Kölliker.)

rw, dorsal ridges: *rf*, medullary groove or canal beginning to close; *uwp*, proto-vertebral plate; *sp*, lateral plate of the mesoblast; *h*, epiblast; *dd*, hypoblast; *ao*, primitive right aorta; *sp*, commencement of division of the mesoblast which forms the body cavity.

Fig. 685.

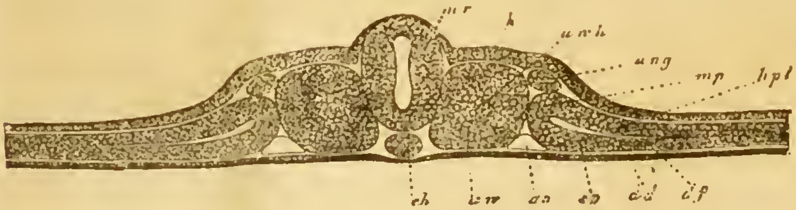


Fig. 685.—Transverse section through the embryo of the chick and blastoderm on the second day. (From Kölliker.)

dd, hypoblast; *ch*, chorda dorsalis; *uw*, primordial vertebræ; *mr*, medullary plates; *h*, corneous layer or epiblast; *uwh*, cavity of the primordial vertebral mass; *mp*, mesoblast dividing at *sp* into *hpl*, parietal, and *df*, visceral laminæ; *ung*, Wolffian duct beginning in the intermediate cell-mass.

3. **Notochord.**—The third rudiment of the embryo is the chorda dorsalis of von Baer or the notochord of more recent authors, which lies in the axis of the vertebral column and cranial base. When somewhat advanced, it extends through the forepart of the embryonic area from the

anterior extremity of the primitive streak to the front of the medullary canal; but, except at its hinder end, it has no immediate connection with the epiblast in which that canal is formed, and lies beneath it in the place which is afterwards occupied by the bodies of the vertebræ and base of the cranium. When fully formed it is also separate from the hypoblast which runs across below it. From this it might appear at first sight that it belongs to the mesoblast, by a part of which it is somewhat later surrounded. But there are still doubts with respect to its origin, that is, whether it is from the mesoblast or hypoblast. The former view is held by Kölliker, and for the higher vertebrates is in some respects tenable: but in elasmobranchs Balfour has found the notochord to *arise* very distinctly from the lower layer by an actual infolding of a linear strip of the cells of that layer, and he, as well as some others, are disposed to attribute the origin of the notochord in the amniota to a similar source. With respect to this view,

Fig. 686.

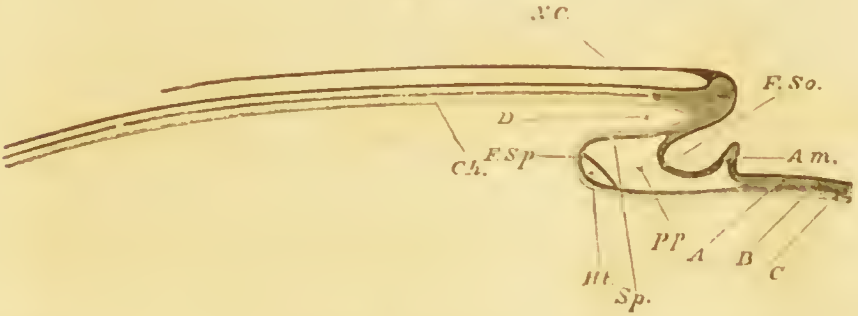


Fig. 686.—DIAGRAMMATIC LONGITUDINAL SECTION THROUGH THE AXIS OF AN EMBRYO-CHICK. (From Foster and Balfour.)

The section is supposed to be made at a time when the head-fold has commenced, but the tail-fold has not yet appeared. *A*, epiblast; *B*, mesoblast; *C*, hypoblast; *FSo*, fold of the somatopleure; *FSp*, fold of the splanchnopleure; *Am*, commencing (head) fold of the amnion; *NC*, neural canal, closed in front, but still open behind; *Ch*, notochord,—in front of it, uncleft mesoblast in the base of the cranium; *D*, the commencing foregut, or alimentary canal; *Ht*, heart; *pp*, pleuro-peritoneal cavity.

Fig. 687.

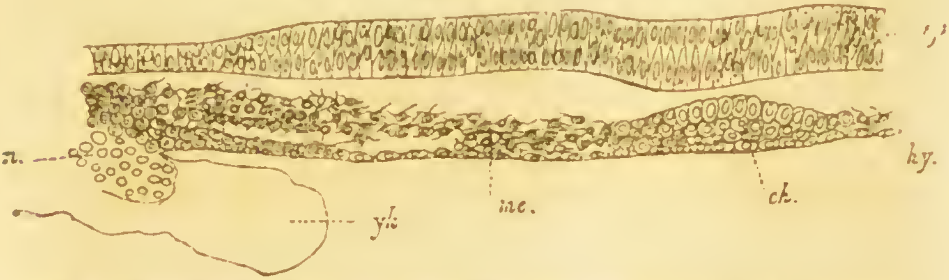


Fig. 687. TRANSVERSE SECTION THROUGH THE EMBRYONIC REGION OF THE BLASTODERM OF A CHICK AT THE TIME OF THE FORMATION OF THE NOTOCHORD. (From Balfour.)

ep, epiblast; *hy*, hypoblast; *ch*, notochord; *me*, mesoblast; *n*, nuclei of the germinal wall *yk*.

it is to be observed that the hinder end of the notochord is directly continuous with the front part of the primitive streak where the mesoblast and epiblast are united, and if it does spring from the lower layer in front of that, it is still possible that in that situation the mesoblastic elements have not yet been differentiated from the hypoblastic in the primitive lower layer.

In the amniota the notochord is mainly cellular in structure; but in some of the lower vertebrates it becomes cartilaginous, and remains as a permanent substitute for the true vertebral column. It is enclosed in a delicate, structureless, or cuticular sheath, outside which in the lower vertebrates, but not in the amniota, another sheath, viz., the elastic, is formed. It is upon the surface of the cuticular sheath in the amniota, and between it and the outer or elastic sheath in the lower vertebrates, that the mesoblastic substance derived from the inner part of the proto-vertebral column is deposited to form the matrix of the future vertebral bodies in a manner presently to be described. The notochord itself takes no direct part in the formation of the cartilaginous or osseous vertebræ; but its remains are to be found for a considerable time within the bodies of the vertebræ and intervertebral plates, as described by H. Müller (No. 159), and others in the human fœtus to a late period, and even in the child after birth.

Fig. 688.

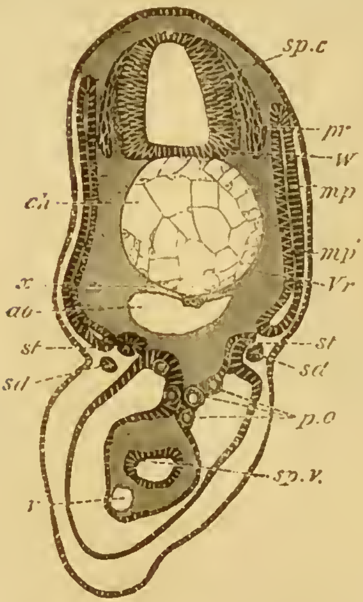


Fig. 688.—SECTION THROUGH THE HINDER PART OF THE TRUNK OF AN EMBRYO-SHARK, TO SHEW THE STRUCTURE AND RELATIONS OF A LARGE NOTOCHORD. (From Balfour.)

spc, spinal canal; *ch*, notochord within its sheath; *ao*, aorta; *mp*, muscle plate; *vr*, rudiment of vertebral body. The figure is more fully described elsewhere.

4. **Mesoblastic or Protovertebral Somites.**—There is still another series of early developmental phenomena, which are nearly contemporaneous with the three previously referred to, and which, though not in themselves immediately concerned in the production of axial rudiments, are yet intimately associated with some of them, and have an important bearing upon the whole after-history of development. Soon after the appearance of the medullary plates and groove, and before the commencement of the closure of the medullary tube, there have appeared on each side of the dorsal ridges a row of well defined, dark, quadrilateral masses, situated in the adjacent column of mesoblast, and separated by clear transverse clefts, or linear intervals.

These masses were for long looked upon as the rudiments of the permanent vertebræ, and were called the *primordial* or *proto-vertebræ*; but they are now known to be of a more comprehensive nature, and receive the appellation of *mesoblastic* or *protovertebral somites*.

In now proceeding to explain the relation of these transversely divided segments to the other phenomena of development, we must recall the fact, referred to in the account of development in general, that the great mass of the mesoblast is very soon divided longitudinally on each side into an inner thick column, in which the transverse segmentation into somites more immediately takes place, and which may be therefore named the *protovertebral columns*, and into flatter *lateral plates*, which again very soon become divided horizontally into an upper, or parietal, and a lower or visceral lamina, and have between them on each side the *body cavity*, or pleuroperitoneal space. At present we have mainly to do with the inner or protovertebral column.

Fig. 689.

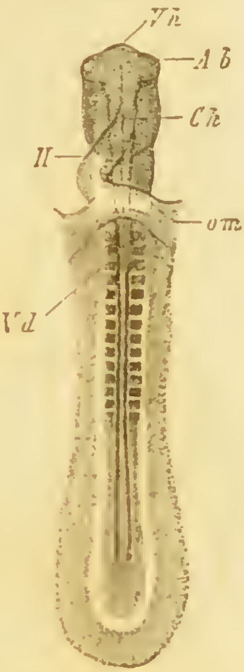


Fig. 689.—EMBRYO-CHICK AT THE END OF THE SECOND DAY, SEEN FROM BELOW. $\frac{15}{1}$ (From Kölliker.)

Vh, forebrain ; *Ab*, primary ocular vesicles ; *Ch*, notochord ; *H*, tubular heart ; *om*, vitelline veins ; *Vd*, entrance to the forepart of the alimentary canal within the cephalic fold ; in the middle part of the embryo, the protovertebral somites are seen (to the number of thirteen pairs) on each side of the canal of the spinal marrow and notochord.

The transverse cleavage of this column, giving rise to the protovertebral segments or somites, begins to appear very early at the side of the dorsal ridges, near the place where they embrace the primitive streak—a region which the subsequent condition shows to correspond with that of the anterior cervical vertebræ. But as the columns extend backwards, they

Fig. 690.

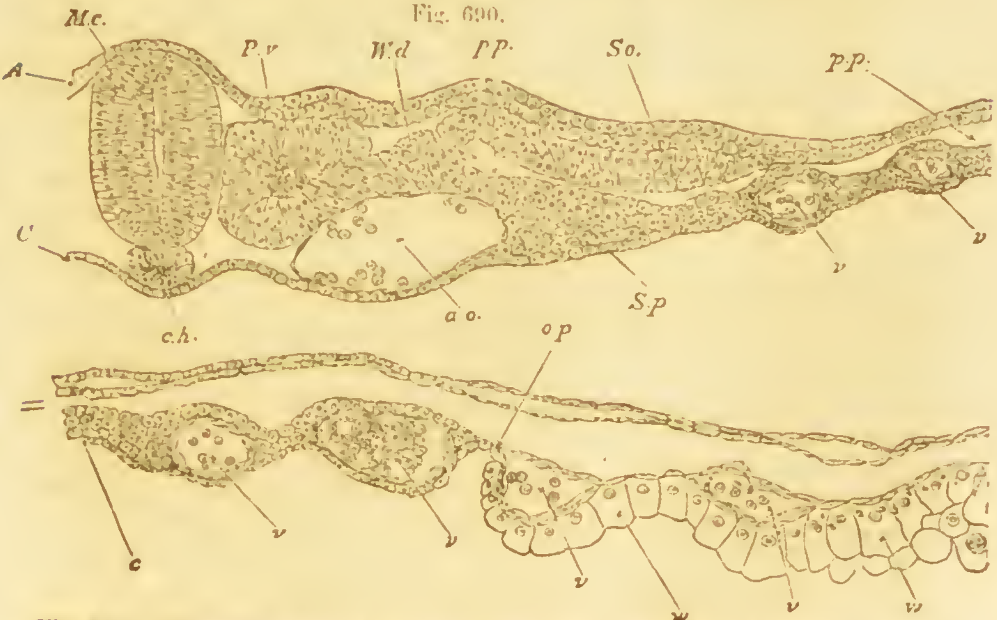


Fig. 690.—TRANSVERSE SECTION THROUGH THE DORSAL REGION OF AN EMBRYO CHICK OF 45 HOURS. (From Balfour.)

A, epiblast ; *C*, hypoblast ; *Mc*, medullary canal ; *Pv*, protovertebra or mesoblastic somite ; *Wd*, Wolffian duct ; *So*, parietal mesoblast ; *Sp*, visceral mesoblast ; *pp*, pleuroperitoneal cavity ; *ao*, left primitive aorta ; *v*, blood-vessels ; *w*, germinal wall ; *ch*, notochord ; *op*, place of junction of transparent and opaque areas.

continue to undergo the transverse cleavage, so as to give rise to an increase in the number of the mesoblastic somites ; and by the time when the medullary canal is closed, there are as many as ten or twelve of them. This process goes on progressively from the cervical into the dorsal, lumbar, sacral and caudal regions, till a number is attained, which corresponds closely with that of the permanent vertebræ, in which, however, the posterior or caudal segments are comparatively late in being formed.

The mesoblastic segmentation is at first confined to the inner or protovertebral column, and it is most distinct in that part ; but in the later development of the walls of the trunk we shall see that a somewhat similar cleavage, or at least a differentiation corresponding with it, extends also into the parietal portion of the lateral mesoblastic plates, so as to give rise in them to the costal and intercostal divisions of the walls.

Fig. 691.

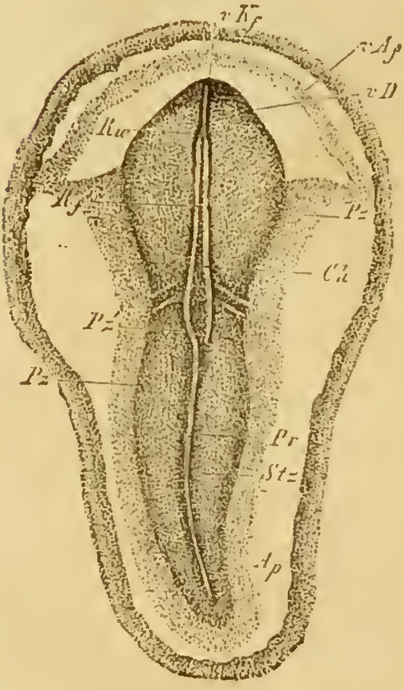


Fig. 691.—AREA PELLUCIDA AND RUDIMENTS OF THE EMBRYO-CHICK OF THE SECOND DAY. $\frac{10}{1}$ (From Kölliker.)

pr, primitive streak and groove ; *Rw*, dorsal or medullary ridges meeting in front; *Rf*, medullary groove ; *Stz*, axial zone ; *Pz*, parietal zone; *Pz'*, two vertebral somites ; *Ch*, notochord ; *Vkf*, cephalic fold ; *vD*, anterior intestinal fold shining through ; *vAf*, anterior or amniotic fold ; *Ap*, area pellucida.

The protovertebral column is at first solid, being composed of firmer columnar cells outside, and looser cellular elements internally. Soon, however, the somites become hollow by the liquefaction of the internal cells ; and it is held that their cavity may be regarded as an extension of the general body cavity, or the intermesoblastic space, which is so apparent and constant in the lateral plates of the mesoblast (Balfour).

The mesoblastic somites by their further changes give rise to the main constituents of the body wall or framework, that is, the rudiments of the permanent vertebræ, and the muscular and dermal plates. These changes consist mainly at first in the separation of a mesial or internal part, in which the vertebral matrices are formed, from the outer parts which are converted into the muscular and dermal plates in a manner which will be more fully described under their respective heads.

II. FORMATION OF THE TRUNK.

1. **Vertebral Column.**—It is from the inner part of the protovertebral column before mentioned that the blastema of the permanent vertebræ is derived, the rapidly growing cells of which extending inwards and upwards from the protovertebral column, surround the whole of the chorda and the medullary canal with the first, or, as it has been called,

the membranous matrix of the vertebræ previous to their cartilaginous differentiation.

The part of this substance which surrounds the notochord forms at first a uniform or undivided tubular enclosure of the chord: but subsequently it shows transverse divisions corresponding to those of the protovertebral somites. The matrices of the arches, which are continuous with those out of which the bodies are formed, extend dorsally round the medullary canal and between it and the superficial epiblast, so as gradually to enclose the neural canal. These rudimental neural arches are from the first separate or in distinct strips, and thus intervals are left between them for the spinal ganglia and nerves which grow out from the nervous centre.

Fig. 692.

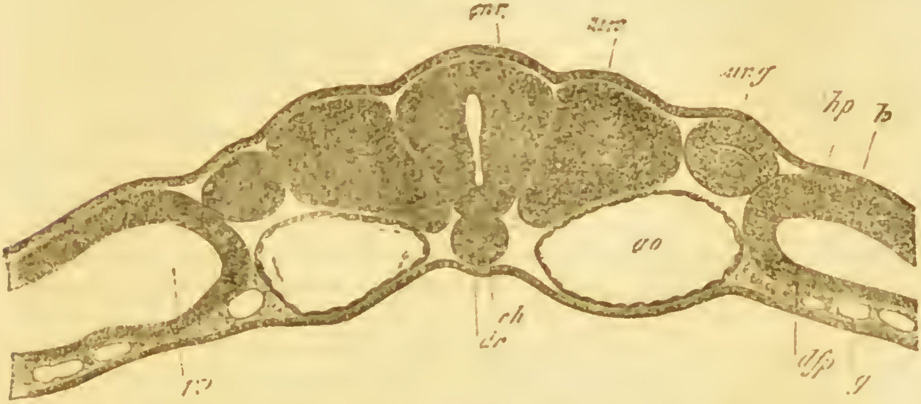


Fig. 692.—Transverse section of an embryo rabbit of 9 days and 2 hours in the middle dorsal region. $\frac{18}{1}$. (From Kölliker.)

mr, medullary tube; *uw*, protovertebral mass; *h*, epiblast; *hp*, parietal mesoblast; *dfp*, visceral division of the mesoblast; *pp*, pleuro-peritoneal cavity between them; *ung*, primitive segmental duct; *g*, vessels in the visceral mesoblast; *ch*, notochord; *dr*, intestinal groove of the hypoblast.

The next step in the formation of the permanent vertebræ is the chondrification or conversion into cartilage of the primitive or membranous matrix. This takes place nearly simultaneously in the bodies and arches, and is found on the fourth day in the chick, and the eleventh or twelfth day in the rabbit, and probably in the fourth and fifth weeks in the human embryo. In the process of chondrification the position of the divisions between the arches remains the same as in the original or protovertebral segmentation; but it is a remarkable fact, discovered by Remak (No. 25), that in the bodies the chondrification is accompanied by a change of such a nature that the separation of the permanent bodies comes to be effected by a new series of clefts, so situated between the former or protovertebral divisions as to cause the permanent intervertebral intervals of the bodies now to fall opposite to the neural arches and muscle plates, and the middle parts of the bodies consequently opposite to the place of the original protovertebral clefts.

While the chondrification of those parts of the vertebral matrices which are to form the bodies is proceeding, a differentiation of the blastema in the interspaces leads to the development of the fibrous substance of the intervertebral discs or ligamentous plates. And here it is right to mention the changes of form in the notochord which are coincident with the formation of the parts surrounding it.

Fig. 693.

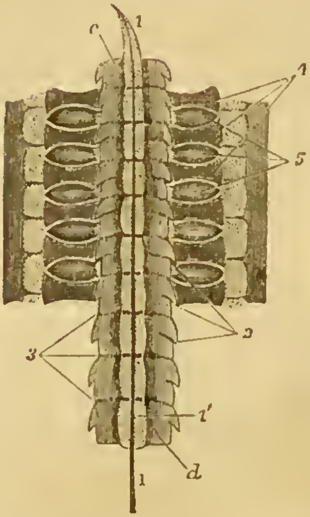


Fig. 693.—Cervical part of the primitive vertebral column and adjacent parts of an embryo chick of the sixth day, showing the division of the vertebral segments. (From Kölliker after Remak.)

1. 1, chorda dorsalis in its sheath, pointed at its upper end; 2, points by three lines to the original intervals of the primitive vertebræ; 3, in a similar manner indicates the places of new division into permanent bodies of vertebræ; *c*, indicates the body of the first cervical vertebra; in this and the next the primitive division has nearly disappeared, as also in the two lowest represented, viz., *d*, and the one above; in those intermediate the line of division is shown: 4, points in three places to the vertebral arches; and 5, similarly to three commencing ganglia of the spinal nerves: the dotted segments outside these parts are the muscular plates.

The notochord does not continue to grow as a whole in the same degree as the permanent vertebral parts, but on the contrary the greater part of it is in the higher vertebrate animals greatly reduced in proportional size, and constricted almost to a lineal filament in the most of its length. In each vertebral segment, however, it presents dilatations or thickenings which differ somewhat in form and position in different animals according to the manner in which the permanent vertebræ are formed.

Fig. 694.

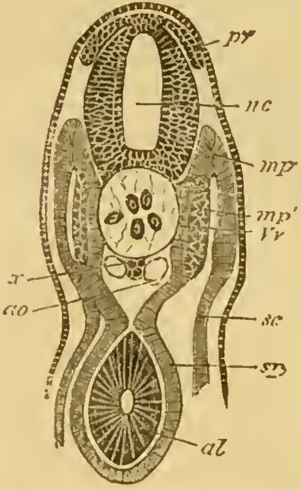


Fig. 694.—Transverse section of early embryo of Pristiurus (Elasmobranchs). (From Balfour.)

nc, neural canal; *pr*, posterior root of spinal nerve; *x*, subnotochordal rod; *ao*, aorta; *sc*, parietal mesoblast; *sp*, visceral mesoblast; *mp*, muscle-plate; *mp'*, portion of muscle-plate converted into muscle; *Vr*, portion of the vertebral plate which will give rise to the vertebral bodies; *al*, alimentary canal.

In mammals the constricted parts of the chorda are situated within the vertebræ, and the principal dilatations are in the intervertebral spaces, where they widen out considerably, and seem to form the basis of the pulpy or gelatinous substance which occupies the centre of the discs (Luschka, 1856, Kölliker).

In osseous fishes the dilatation is also intervertebral, and the growth of the chorda proceeds to such an extent as to give rise to the large double cone of soft and gelatinous substance which occupies the conical hollows of the biconcave vertebral bodies. But in birds, reptiles, and amphibia, the dilatations of the notochord are within the bodies of the vertebræ, and as in these animals articular cavities are developed between the vertebræ, the vestiges of the notochord very soon disappear from the intervertebral spaces, while they remain much longer visible in the bodies (Gegenbaur).

In mammals, therefore, the cartilaginous matrix of each vertebral body (and the first subsequent ossification) begins in the centre immediately round the constricted part of the notochord: but it is also to be noted that within each vertebra, at a somewhat later period, two small dilatations in the narrow part of the notochord are to be observed, opposite the intervals between the central ossifying nucleus and the epiphysial plates (see fig. 696).

Fig. 695.

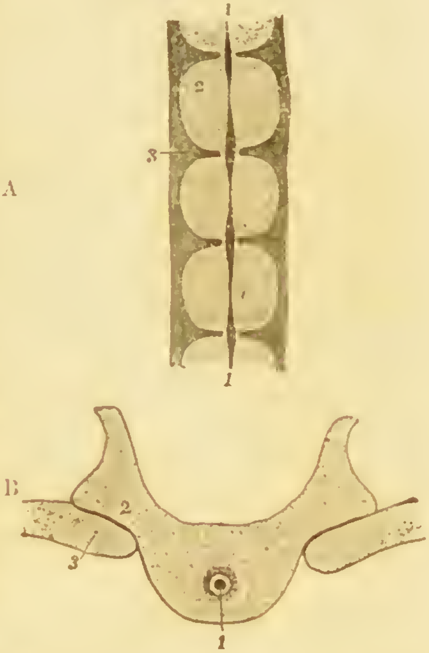


Fig. 695.—SECTIONS OF THE VERTEBRAL COLUMN OF A HUMAN FŒTUS OF EIGHT WEEKS. (From Kölliker.)

A, tranverse longitudinal section of several vertebræ. 1, 1, chorda dorsalis, its remains thicker opposite the intervertebral discs; 2, is placed on one of the bodies of the permanent vertebræ; 3, on one of the intervertebral discs.

B, transverse horizontal section through a part of one dorsal vertebra. 1, remains of the chorda dorsalis in the middle of the body; 2, arch of the vertebra; 3, head of a rib.

In birds, reptiles, and amphibia, on the other hand, the formation of cartilage and the subsequent ossification of the vertebral bodies begin at the intervertebral surfaces, and extend from thence inwards upon their central part.

The neural arches of the vertebræ arise from a thin sheet of blastema which extends dorsally from the protovertebral columns on each side, and the two sheets, meeting each other mesially along the back (membrana reuniens superior of Remak), completely enclose the medullary canal. This takes place on the third day in the chick, and is therefore considerably later than the investment of the notochord with the vertebral elements of the bodies.

Fig. 696.

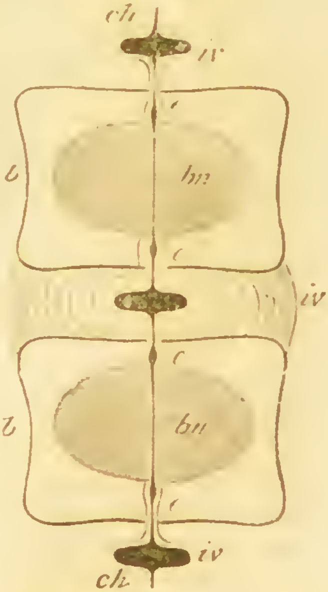


Fig. 696.—DIAGRAM TO SHOW THE POSITION OF THE ENLARGEMENTS OF THE NOTOCHORD IN PASSING THROUGH THE VERTEBRAL COLUMN. Half the natural size. (After Kölliker, A.T.)

ch, notochord; *b*, bodies of two vertebræ; *ir*, intervertebral plate with the wide enlargement of the notochord; *bn*, ossific nucleus of the bodies of the vertebræ; *c*, slight dilatations of the notochord opposite the epiphysial plates.

The membranous investment of the medullary canal doubtless contains the elements not only of the neural vertebral arches, but also those of the dura mater and other coverings of the central nervous organs. This investment does not however form a complete tube, but is interrupted or open at the intervals occupied by the spinal ganglia and nerves emanating from the medullary centre. When chondrification of the vertebral matrices takes place the neural arches are found to be connected and at first continuous with the forepart of each vertebral body as reconstituted by the secondary transverse division, the intervals for the spinal nerves and ganglia being opposite the posterior part of the bodies and the intervertebral plates.

The history of the further development of the vertebral column belongs rather to that of the ossification of its several parts, which has been described in the first volume. It may be stated in addition here that in the human embryo the process of chondrification of the bodies begins between the fourth and fifth weeks (Kölliker), and is already completed by the sixth or seventh, soon after which ossification commences. In the arches the chondrification is about a week later in commencing, but the ossific deposit, which begins in the eighth week, is slightly earlier in them than in the bodies.

The whole number of cartilaginous vertebral matrices varies from 33 to 35, there being occasional subordinate variations in the number developed in each division of the trunk. The maximum number of coccygeal pieces is six according to E. Rosenberg (No. 166).

The formation of cartilaginous matrices for the vertebral arches begins first in those of the dorsal region, and extends from thence forwards into the cervical vertebræ and basis of the skull, and backwards into the lumbar and sacral vertebræ; but the dorsal extension of the cartilaginous matrix ceases to be formed in the hinder sacral and coccygeal vertebræ where these arches are afterwards deficient.

Rathke first showed (No. 14, ii., 1839) that the body of the Atlas vertebra is merged in the odontoid process of the second or axis vertebra; and that in the tortoise the chorda runs through the odonto-occipital ligament. This was confirmed for mammals by Joh. Müller, and later by Robin and Hasse. According to some the anterior arch of the atlas might belong to the subcentral or hæmal series of arches; but it would appear that the homology of this part is not yet fully determined.

2. **Ribs and Sternum.**—As completing the skeleton of the trunk of the body, it will be convenient to describe here the development of the ribs and sternum.

The ribs are extensions of the vertebral blastema in the thoracic parietal plate of the mesoblast; and their matrices are at first continuous with those of the vertebræ. They undergo early chondrification along with the vertebræ, but become separate from them before ossification commences. At their ventral extremities, as was first shown by Rathke in 1838 (No. 158), the seven which are afterwards to be sternal ribs of each side come to be united together by a longitudinal strip of cartilage; and the subsequent union of these two strips from before backwards gives rise to a single median piece of cartilage, which represents the manubrium and body of the sternum. The xiphoid cartilage is of later formation. (See Parker, No. 161.) This mode of origin and development of the sternum is interesting in connection with the malformation of fissure or median division of that bone which has been observed in many different gradations.

3. **Muscle Plates and Muscles.**—The muscles of the trunk derive their origin from the *muscle plates,* which are developed in the upper and outer part of the protovertebral column, in which the primary segmentation of the mesoblastic somites remains quite distinct. When the inner part of the protovertebral column has extended itself into the vertebral matrices of the bodies and arches (as before described), the muscle plates are found to consist of two laminæ, an inner and an outer, between which there is a space which is said to be in communication at first with the body cavity. This space is necessarily subdivided for each muscle plate. As development proceeds, however, the opening into the general body cavity being closed, the outer and inner layers of the plates lie more nearly applied together. The process of conversion into permanent muscular tissue by differentiation of the cells

has been shown by Balfour to begin first in the inner layer. (See fig. 694 and 698, *mp'*.)

The plates somewhat overlap one another; and connective tissue is deposited in the intervals between them, which in the lower animals is the basis of permanent intermuscular septa, and in the higher of temporary structures of the same kind, and of the perimysial sheaths, &c.

Fig. 697.

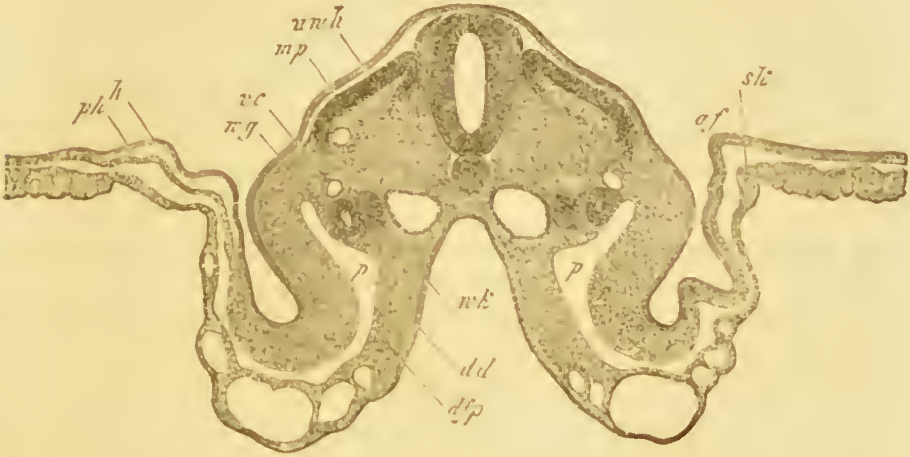


Fig. 697.—TRANSVERSE SECTION THROUGH THE MIDDLE OF AN EMBRYO-CHICK OF THE THIRD DAY, WITH OPEN AMNION. $\frac{80}{1}$. (From Kölliker.)

af, fold of the amnion consisting of *h*, epiblast, and *ph*, parietal mesoblast; *sk*, lateral fold of hypoblast and visceral mesoblast; *mp*, muscle-plate; *uwh*, remains of proto-vertebral cavity; *vc*, vena cardinalis; *wg*, segmental duct; *wk*, segmental tube; *p*, peritoneal cavity; *dfp*, visceral mesoblast with vessels; *dd*, hypoblast and intestinal groove.

In the progress of growth the muscle-plates extend to near the middle dorsal line; they reach also downwards in a ventral direction, and in part under the vertebral bodies, and they pass into the walls of the body externally, and thence ultimately into the limbs.

Fig. 698.

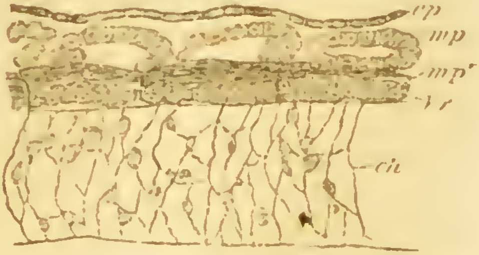


Fig. 698. — HORIZONTAL SECTION THROUGH THE TRUNK OF AN EARLY EMBRYO OF SCYLLIUM, PASSING THROUGH THE NOTOCHORD. (From Balfour.)

ch, notochord; *ep*, epiblast; *vr*, rudiment of vertebral body; *mp*, muscle-plate; *mp'*, portion of muscle-plate already converted into longitudinal muscles.

Both layers of the muscle-plate are converted into muscles, but while it is undoubted that all the voluntary muscles proceed more or less directly from the mesoblast and probably from the muscle-plates, it is still questioned by some whether the hypaxial as well as the epaxial muscles proceed from this source alone.

In the early stages of muscular development in the amniota the myotomes are divided by transverse intermuscular septa, and thus retain much of the character of protovertebral segmentation which is familiar as a marked feature of their structure in the lower vertebrates,—a fact of great morphological significance.

The formation of the longer muscles in the higher vertebrates takes place by the disappearance of the intermuscular septa and the longitudinal union of the fasciculi of successive myotomes. In the trunk the direction of these, especially of those most closely attached to the vertebral skeleton, remains for the most part longitudinal, but the more superficial muscles, and especially those connected with the limb-girdles, change their direction as well as their form to a great extent.

According to Balfour, the length of each muscular fibre derived from one of the cells of a muscle-plate is equal to the breadth of the myotome in which it is situated.

The division of the trunk muscles into an upper or dorso-lateral and a lower or ventro-lateral group by a horizontal septum, extending outwards from the transverse processes of the vertebræ and corresponding with that which belongs to the lateral line of the lower vertebrates, is only faintly indicated in the adult of the amniota.

4. **Body Walls.**—Along with the changes now mentioned as leading to the formation of the principal parts constituting the framework of the vertebrate body, there is to be noticed a later series of phenomena which are more immediately related to the production of the outer walls by which the visceral cavities and viscera are enclosed.

The parts hitherto described, which are mainly axial, lie prone and comparatively flat upon the surface of the yolk, and they are also chiefly formed by folding and differentiation of the two upper layers without any direct participation of the hypoblast, which passes thin and flat across the embryonic area below the medullary canal and notochord. But in the further progress of development, and in part simultaneously with the changes already described, the inflection of the peripheral parts of the blastoderm downwards or in a ventral direction, along with their extension and thickening, gives rise to the formation and enclosure of the thoracic, abdominal and pelvic cavities of the trunk.

The first of the folds now referred to, named the cephalic, begins to be formed much earlier than the rest, indeed its rudiment is to be perceived very soon after the appearance of the medullary plates and groove. It involves all the layers of the blastoderm, and is of such a nature as to pass downwards on each side, and gradually progressing backwards, to enclose a space within the layers which, as it is lined by the hypoblast, necessarily comprehends a part of the alimentary canal. This fold also encloses the rudiment of the heart when that organ comes to be formed, extending backwards below the cephalic part of the embryo as far as the fovea cardiaca, and closing in the cephalic part of the alimentary cavity anteriorly by the inflection of the three blastodermic layers below the primitive brain or cranium.

Somewhat later a similar inflection of all the layers occurs at the caudal extremity of the embryo, but this is much shorter than the cephalic fold, and includes therefore a comparatively small portion of the alimentary canal, viz., the caudal and primitive cloacal part, which, like the anterior, is at first completely closed by the inflection of the layers. (See fig. 660.)

Between the cephalic and caudal folds, that is, along the sides of the axial embryo in the greater part of what afterwards becomes the abdominal cavity, the walls of the body also undergo a downward inflection, and as these are continuous before and behind with the cephalic and caudal folds, the place of their meeting, from being at first a wide and elongated gap between the cavity enclosed in the embryo and the peripheral parts of the blastoderm, becomes at last, by the gradual infolding of the edges bringing them more and more together, the narrower constriction which, from its later relations, is named Umbilical.

As, however, the infolding parts are everywhere composed of the parietal and visceral plates separated by the body cavity, we have to distinguish, in the umbilical constriction, the outer wall of the body formed of epiblast and parietal mesoblast, from the wall of the alimentary canal composed of visceral mesoblast and hypoblast.

Beyond the umbilical constriction the outer or parietal plate is in continuity with the amnion, and the deeper or visceral plate, when the intestine assumes a tubular form, is continuous with the yolk sac.

It thus appears, as was first shown by Von Baer, as the result of the earlier changes of vertebrate development, that there are formed two main tubular cavities, the one above the other below the notochordal axis; the upper being the cranio-vertebral, enclosing the great nervous centre, and the lower being the visceral cavity, in which the alimentary canal, heart, lungs and other nutritive organs are contained.

There is not at first any marked distinction between the head and the trunk in the axial part of the embryo, nor is there apparent any neck or cervical constriction. The changes which lead to this distinction are of later occurrence, and will be considered hereafter in connection with the description of the development of the head. Here it will suffice to state that the cephalic part of the axial body is at first only cranial, and that the face is formed later by the outgrowth of various bars and processes round the sense-capsules, mouth and pharynx, and mainly from the anterior and ventral aspects of the cranial part.

The caudal extremity of the embryo always consists of a prolongation of the vertebral column containing the notochord and covered by the usual epiblast. This extends beyond the place of the primitive caudal fold, and consequently the hinder part of the alimentary canal and organs connected with it fall short of the extremity of the tail.

The tail of the embryo is the seat of an incurvation which is most commonly ventral, but is sometimes combined with torsion, as is seen in a remarkable degree in serpents and in various degrees in other animals.

5. **Flexion and Torsion of the Embryo.**—Simultaneously with the occurrence of the early formative changes before adverted to, there take place others which affect the external form and attitude of the embryo. These consist mainly of three kinds of flexure and incurvation accompanied by various degrees of growth in the proportions of the parts in which they take place. The first may be named the

Fig. 699.

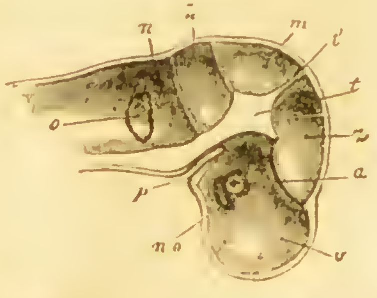


Fig. 699.—LONGITUDINAL SECTION THROUGH THE HEAD OF AN EMBRYO OF FOUR WEEKS. (From Kölliker.) $\frac{10}{1}$

v, anterior encephalic vesicle, cerebral portion; *z*, interbrain; *m*, midbrain; *h*, cerebellum: *n*, medulla oblongata; *no* and *a*, optic vesicle; *o*, auditory depression; *t*, centre of basi-cranial flexure; *t'*, lateral and hinder parts of tentorium; *p*, the fold of epiblast which forms the hypophysis cerebri.

principal cephalic flexure, and consists in a strong angular flexion of the cranial cavity in a ventral or downward direction in the region of the midbrain and sella turcica of the cranium. The second is, in birds, a more extended curvature of the vertebral column in the region of the neck and thorax, but in mammals more frequently in the lower cervical region only, such as to bend together the head and trunk of the body. The third inflexion is of a different nature from the first two, usually preceding them in its commencement, and is more marked in birds and reptiles than in mammals; though it also occurs in some of the latter animals. This, as seen in birds, consists in a torsion of the embryo on its axis to the extent of a quarter of a circle, by which, beginning from the head, the embryo, from being at first flat and prone, comes gradually to have the left side lowest and applied to the blastoderm. In rare instances the direction of this torsion is reversed, and the embryo lies on its right side.

Fig. 700.

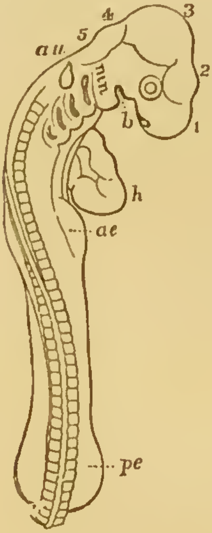


Fig. 700.—Outline of the embryo-chick at the end of the third day, to show the inflections of the body and the commencement of the limbs. (After His.)

1 to 5 the cerebral vesicles; *h*, the mouth; *mn*, the lower jaw, and behind that the branchial bars and clefts; *au*, the auditory vesicle; *h*, the heart; *ae*, anterior extremity; *pe*, posterior extremity; the hinder part of the body is still prone upon the surface of the yolk, the head is now lying on its left side and between is seen the gradual torsion of the vertebral column and trunk.

This torsion is not so constant in mammals as in birds, and it not unfrequently happens that along with the ventral incurvation of the body, the forepart, notched off from the rest of the blastoderm, sinks deeply into a hollow on the surface of the yolk.

There are, however, many differences in the early attitude of the embryo of mammals in connection with the varieties in the form and size of the yolk sac and other membranes.

III. ORIGIN AND FORMATION OF THE LIMBS.

The limbs arise as outgrowths from the lateral part of the trunk in determinate parts of the thoracic and pelvic regions, and, though not presenting any original protovertebral segmentation, are in some respects to be regarded as lateral extensions of vertebral somites in these situations. They make their first appearance after the completion of the primary steps in the development of the axial structures of the trunk, about the end of the third day in the chick (see fig. 700), and in the third and fourth week in the human embryo. They have the form of semilunar plates of parietal mesoblast covered with epiblast, budding out as it were from the lateral ridge, near the line of separation of the mesoblast into its parietal and visceral laminæ, and close to the outer margins of the muscle-plates.

Each limb consists of the supporting arch or girdle, thoracic or pelvic, which is sunk in the substance of the lateral ridge, and makes little or no appearance externally, and of the free or projecting part which is at first quite simple, but soon becomes divided into the distal, middle and proximal segments.

Fig. 701.

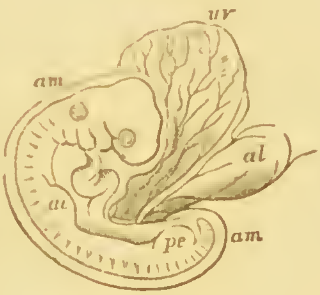


Fig. 701.—Lateral view of human embryo between three and four weeks, to show the commencing extremities. (A.T.)

am, the amnion surrounding the embryo; *uv*, umbilical vesicle; *al*, allantoid pedicle; *ac*, anterior extremity; *pe*, posterior extremity; the Wolffian ridge passing between them.

The lappet or bud which first shows itself appears to correspond most nearly with the distal segment comprising the hand or foot, the other two segments being successively developed between it and the root or girdle at an early period. The new part shows itself first by the notched separation of a segment between the terminal one and the side of the body, corresponding to the forearm or lower leg, and this is followed by the development in a similar manner of the proximal segment, the upper arm or thigh.

While these changes in the limbs occur, other advances in form and structure are discernible, first, in the appearance of four slight notches in the free margin of the distal segment, indicating the commencement of the pentadactylar division into the elements of fingers or toes, the formation of which is even more marked by the differentiation of the deeper substance of the distal segment; second, in the occurrence of an inflection between the middle and proximal segments, the hollow of which in the fore-limb looks forward, and in the hind limb backwards with reference to the axis of the trunk; and third, in the rapid progress of the deeper textural differentiation which leads to the development of the several components of the limbs, such as the skeletal, muscular, dermal, nervous and vascular parts.

Fig. 702.

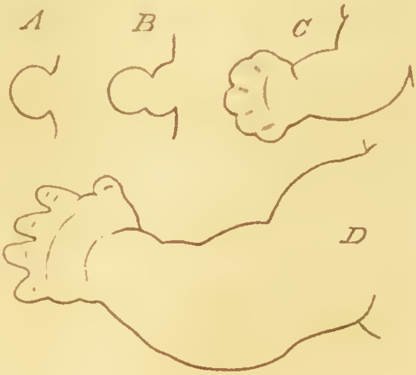


Fig. 702.—Outlines of the anterior extremities of human embryoes at different ages. (A.T., after His.)

A, at four weeks; *B*, at five weeks; *C*, at seven weeks; *D*, at nine or ten weeks.

The rudimentary limbs consist at first entirely of a mass of nearly uniform blastemic cells derived from the parietal mesoblast, covered superficially by the cuticular epiblast, which always presents at its extremity a peculiar pointed or conical cap of thickened epidermis. (See fig. 703.)

The development of the parts of the limb now referred to, both in its larger features and in its histological characters, is usually somewhat more in advance in the anterior than in the posterior extremities.

Fig. 703.

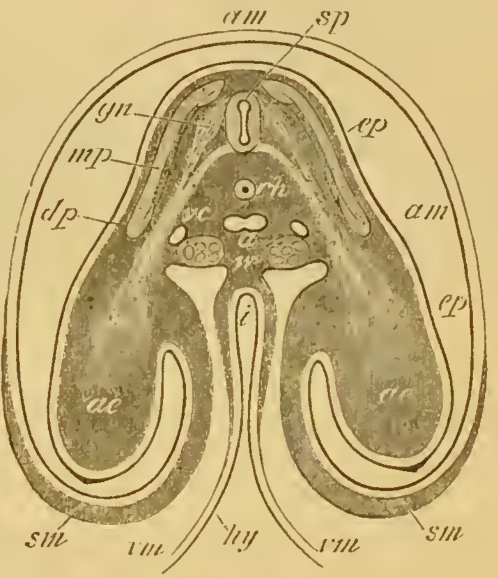


Fig. 703.—Transverse section of the body of the chick at the level of the anterior extremities. (From Remak.)

am, amnion in its cephalic fold ; *ep*, epiblast ; *sm*, parietal mesoblast ; *vm*, visceral mesoblast ; *sp*, spinal marrow ; *gn*, spinal ganglion and nerve roots ; *mp*, muscle-plate ; *dp*, dermal plate ; *ch*, notochord, with vertebral matrix round it ; *a*. aorta (the two uniting into one) ; *vc*, cardinal veins ; *w*, mesentery and Wolffian bodies ; *ae*, anterior extremities composed of mesoblast, *m*, and covered with epiblast thickened at the point ; *i*, intestinal canal open below into the yolk sac ; *hy*, hypoblast.

Attitude and position of the Limbs.—From the manner in which the primary lappet or limb-plate grows from the side of the axial part of the trunk, it is obvious that at first it must present a dorsal and a ventral surface, corresponding respectively with those of the embryo body, and if we trace the subsequent changes which bring out the features of the later form, we shall find them such as to show that the original dorsal aspect is the extensor and the ventral aspect is the flexor surface of the limb ; and further that when the distinction of the subordinate parts begins to be established, the thumb and great toe, reckoned in descriptive anatomy as the first of the series, and corresponding with the radial and tibial borders of their respective limbs, are directed forwards or preaxially, while the fifth toes, with the ulnar and fibular borders of their respective limbs, are directed backwards or postaxially.

As development proceeds, the two primary lappets, from being at first simple lateral extensions from the trunk, come to be folded ventrally or against the body of the embryo, the anterior with something of a backward, and the posterior with a forward direction. But they have now also undergone other changes, by which the attitude of the distal segments is affected differently in the two limbs, in this respect, that in the fore-limb the flexure between the proximal and the middle segments is directed forwards or ventrally, while in the hinder limb it is in the reverse direction, that is backwards or dorsally. In the human body this flexure does not involve any considerable departure from the original relation of the extensor and flexor surfaces to those of the trunk, although in the adult it may appear to do so in consequence of the limb hanging somewhat obliquely in a direction parallel to the main axis of the trunk. But in the hind limb it is obvious that there must be from an early period a certain amount of rotation of the whole limb or from the hip-joint downwards, which brings the extensor surface of the thigh, lower leg and foot forwards, and carries the flexor surface of these parts backwards.

Fig. 704.

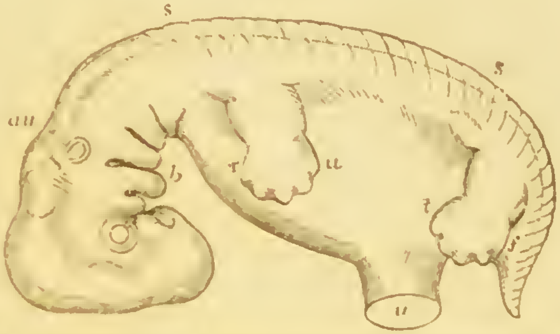


Fig. 704. — Diagrammatic outline of the profile view of the human embryo of about seven weeks, to show the primitive relations of the limbs to the trunk. (Allen Thomson.)

r, the radial (preaxial), and *u*, the ulnar (postaxial) border of the hand and fore-arm; *t*, the tibial (preaxial), and *f*, the fibular (postaxial) border of the foot and lower leg. (The foot is represented at a somewhat more advanced stage than the rest of the embryo.)

In quadrupeds, however, it is different as regards the fore-limb, for in them, while there is the same kind and degree of rotation in the hind-limb, equal to a quarter of a circle, as in man, there is also a rotation of the humerus outwards, and frequently a forward displacement of the upper end of the radius with more or less complete pronation of its lower extremity, which brings the palmar aspect of the fore-limb towards its original ventral position; this becoming most completely restored when in the state of extension more or less of the forefoot supports the body on the ground. In this the pollex, like the hallux, is placed towards the mesial side. This rotation of the fore-limb, amounting in all to half a circle, is made up of an outward rotation of the humerus at the shoulder-joint and an inward rotation of the fore-arm at the elbow-joint.

In the development of the several deeper components of the limbs it is to be observed in the first place with respect to the skeleton, that the formation of the bones with their accessory parts takes place by a primary differentiation of the blastema into cartilaginous matrices and fibrous or membranous parts, and the subsequent calcification of the cartilages and subperiosteal ossification, in the manner fully described in the histological part of this volume (p. 101), to which, as well as to the history of the progress of ossification in the several bones, given in the first volume, the reader is referred.

It may be further stated here that in all the bones of the limbs, with the exception of the terminal phalanges, the processes of cartilaginous calcification and true ossification begin at the middle and extend thence towards the ends of the bone-matrices, but in the terminal phalanges these processes commence in the distal ends and proceed from thence inwards upon the rest of the bone-matrices,—a fact of considerable morphological significance with reference to the determination of the homologies of the terminal elements of the limbs in the lower vertebrates. (Dixey, No. 172.)

It may also be mentioned here that it has been found by Henke and Reyher (No. 165) that in the human embryo of the seventh and eighth weeks there is a distinct cartilage, representing the os centrale of animals, placed between the scaphoid, magnum and trapezium cartilages, but this central cartilage gradually diminishes and passing dorsally disappears in the course of the third month, without either uniting with any of the neighbouring bone-matrices or undergoing ossification.

Muscles.—With respect to the muscles of the limbs, it seems still doubtful whether they proceed directly from the muscle-plates, which it is admitted reach the root of the limbs by their outer edge, or whether they arise locally. It may be that the muscles take their origin in both of these modes, the trunk-muscles which are attached to the limbs being most probably formed in connection with the muscle-plates.

The Joints.—The differentiation of the blastemic tissues into the parts which are to form the joints takes place at the same time that the primary chondrification shows itself for the formation of the bone-matrices, and is coincident also with the commencement of the perichondrium and the fibrous and vascular osteogenic elements. There are at first no joint-cavities, and the fibrous or connective tissue, forming a sort of articular plate between the bone-matrices, may therefore be said to unite them by syndesmosis. But very soon, or in the human embryo of from seven to eight weeks, when chondrification is complete, narrow slits make their appearance in the places of the future joint-cavities, and the fibrous structures retiring from the interior towards the surface, the cavities undergo enlargement into their permanent form,—a process which approaches completion in the human embryo of four months.

The ligaments are developed from the remains of the fibrous matrix, in connection with the earlier perichondrium which becomes converted afterwards into permanent periosteum.

Nerves and Blood-vessels.—The nerves of the limbs probably differ from their other constituents as regards their origin, in this respect, that they are prolonged into the limbs by extension from the nerve-roots which emanate from the spinal marrow. Similarly the blood-vessels of the limbs arise to some extent by prolongation from those of the trunk; but no doubt there are also many blood-vessels formed locally or within the mesoblastic tissue of the limbs; and it is not known to what extent the growth of the nerves in the peripheral parts of the trunk and limbs may be due to a similar local development.

IV. EXTERNAL COVERING OF THE BODY AND LIMBS.

The epiblast which is not employed in the formation of the nervous centre or other deeper parts remains as the source of the epidermis and its appendages. This covers all the external surface of the body and penetrates into such cavities as the mouth and nasal fossæ, &c., whose surfaces are in original continuity with it. Besides the two layers distinguished as corneous and mucous in the epidermis, it gives rise to the hairs and nails, and the teeth of mammals, to the feathers of birds and to the scales and horny plates of these or other animals. It is, however, closely united with the subjacent dermoid tissue, from the blood-vessels of which the materials for its formation and that of its appendages are derived.

The true skin or dermis, of a much more complex structure, is formed entirely from mesoblast, and arises in close connection with the muscular plates. The fasciæ and connective tissues spring from the same source.

The cellular structure of the sebaceous and sudoriferous glands, and also of the mammæ, is all of true epiblastic origin ; but their blood-vessels, connective tissue, and other superadded parts are derived from mesoblast.

V. FORMATION OF THE HEAD.

The distinction between the head and trunk by the formation of a cervical constriction is a change of comparatively late occurrence, but even long before this constriction appears, the characteristic features of the parts in these three regions have become apparent. The head may be said to consist at first wholly of the cranial part,—the face being developed at a later period from a series of outgrowths or bars which proceed downwards and forwards from the base and front part of the cranium. The head in its primitive cranial form is, of course, covered externally like the rest of the body by the epidermis derived from the epiblast, and between this and the primary medullary wall of the great nervous centre a layer of mesoblast is soon interposed, from which originate the coverings of the brain, the muscular plates, the cartilaginous and bony elements, the true skin, the connective tissue, blood-vessels, and other components of the more advanced cranial walls. This mesoblast may be regarded as a cephalic prolongation of the protovertebral plates of the trunk, but as we shall see hereafter without undergoing obvious metameric segmentation.

Fig. 705.

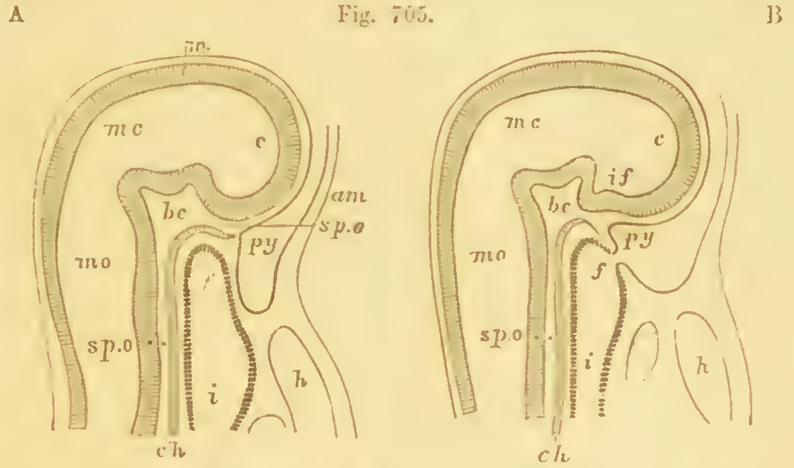


Fig. 705.—Vertical section of the head in early embryoes of the rabbit. Magnified. (From Mihalkovics.)

A. From an embryo of five millimetres long.
B. From an embryo of six millimetres long.

In A, the faucial opening is still closed ; in B, it is formed ; *c*, anterior cerebral vesicle ; *mc*, meso-cerebrum ; *mo*, medulla oblongata ; *m*, medullary layer ; *if*, infundibulum ; *am*, amnion ; *spe*, spheno-ethmoidal, *bc*, central (dorsum sellæ), and *spo*, spheno-occipital parts of the basis cranii ; *h*, heart ; *f*, anterior extremity of primitive alimentary canal and opening (later) of the fauces ; *i*. cephalic portion of primitive intestine ; *ch*, notochord ; *py*, buccal and pituitary involution.

The notochord, as already stated, extends for some distance into the base of the cranium, and is there imbedded in a mass of tissue, the *investing mass* of Rathke, which afterwards becomes the *parachordal* cartilages forming the principal matrix of the future bony walls of the cranial base, as far forward as the sella turcica. From this place the cartilaginous rudiments are continued forwards in two more or less united bars named the *trabeculæ cranii* by Rathke, and having a space between them posteriorly which is afterwards the seat of the pituitary gland. The trabeculæ stretch forward until they reach the region of the olfactory pits, and enclose that depression on each side with the nasal cartilages developed from them in front.

The basis cranii in this view may be considered as composed of a posterior chordal part the *occipito-sphenoid*, and an anterior achordal part the *spheno-ethmoid.*

The facial part of the head, on the other hand, is mainly composed of plates or bar-like growths from the front and sides of the base of the cranium which may be distinguished as of two sets, according as they are placed in front of or behind the mouth or buccal cavity. But the mouth as we know it at a later period, either in the form of a cavity of the face or as the anterior aperture of the alimentary canal, has at first no existence, the anterior extremity of that canal being closed by the original cephalic fold of the blastoderm, and the forehead, nose, cheeks, jaws and lips being as yet entirely absent.

Fig. 706.

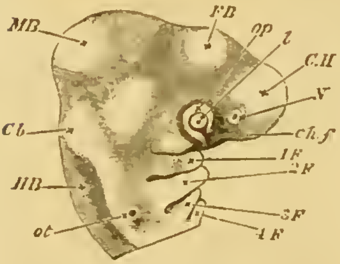


Fig. 706.—Side view of the head of an embryo-chick of the third day. (From Balfour.)

CH, cerebral hemispheres; *FB*, thalamencephalon; *MB*, midbrain; *Cb*, cerebellum; *HB*, medulla oblongatæ; *N*, nasal pit; *ot*, auditory vesicle not yet closed externally; *op*, optic vesicle, with *l*, the lens, and *chf*, the choroidal fissure (in mesoblast); 1*F*, the first visceral fold or plate, the superior maxillary fold slightly indicated above it; 2, 3, 4*F*, the second, third and fourth visceral plates with the visceral clefts between them.

The mouth therefore is formed by a transverse cleft or depression between facial bars or plates, and owes its production as a cavity more to the development outwards of these bars, than to the depression inwards of the anterior cranial wall in which it is situated. The later formed buccal aperture or communication with the pharynx is produced only on the fifth day in the chick by a wearing through or absorption of the epiblast and hypoblast of the original cephalic fold at the fauces or anterior part of the primitive alimentary cavity. The facial plates which are in front of the future mouth, and are sometimes named *preoral arches*, consist mainly of the single or median fronto-nasal plate, and in lateral pairs of the external nasal and maxillary plates, the last constituting the basis of the upper jaw, and arising in connection with the mandibular next mentioned.

The subcranial plates or bars which lie behind the mouth, and are, therefore, named *postoral arches*, consist in the amniota of five pairs of wall plates, meeting each other ventrally below the mouth and pharynx. The first of these, named mandibular, is that in which the lower jaw is formed. The second pair of bars is the seat of development of the upper part of the hyoid bone, and is therefore named hyoid. The three following bars correspond in their relations with the most anterior of the arches which support the developed gills of aquatic vertebrates, and may therefore be strictly named branchial,—a name which was not inappropriately given to the whole series by their discoverer, Rathke.

The skull like the rest of the skeleton is at first entirely membranous;

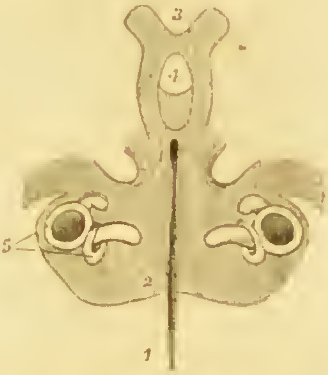
chondrification then takes place in certain parts of the blastema; and ossification follows in the third stage, partly in the cartilaginous and partly in the membranous matrices.

1. **The Cranium.**—The basal portion of the cranium, as already stated, consists primarily of two fundamental parts. Of these the posterior is distinguished, as before stated, by the presence of the prolongation of the notochord within it as far forward as the part of the skull which afterwards becomes the dorsum sellæ. This portion, comprehending the parachordal plates which surround the anterior extremity of the notochord, contains the matrix of the future basi-occipital and basi-sphenoid cartilages. By its later extension to the sides, it forms the matrix of the exoccipitals and the periotic mass of cartilage which surrounds the primary auditory vesicles. The main part extends forward below the posterior and middle primary encephalic vesicles, ending at the pituitary fossa.

Fig. 707.—The lower or cartilaginous part of the cranium of a chick of the sixth day. (From Huxley.)

1, 1, chorda dorsalis; 2, the shaded portion here and forwards is the cartilage of the base of the skull; at 2, the occipital part; at 3 the prolongations of cartilage into the anterior part of the skull called *trabeculæ cranii*; 4, the pituitary space; 5, parts of the labyrinth.

Fig. 707.



The *spheno-ethmoid* portion of the basis cranii contains the matrix of the presphenoid, and the septal-ethmoid cartilages. It is mainly produced in connection with the trabeculæ cranii, which are in direct continuity with the anterior part of the parachordals.

The trabecular part lies below the anterior encephalic vesicle, and becomes greatly modified in connection with the expansion of the cerebral hemispheres and the development of the nasal fossæ and mouth, together with the other parts of the face.

The three principal sense organs, it may here be stated, the nose, eye, and ear, formed in connection with their several primary nervous parts derived respectively from the cerebral hemispheres, the thalamencephalon, and the third primary vesicle, are interposed between the rudimentary parts of the head as follows, viz.: the nose between the frontal, ethmoid and maxillary; the eye between the frontal, sphenoid, ethmoid and maxillary; and the ear between the basi-occipital, exoccipital and alisphenoid. Of these the auditory vesicles come to be surrounded by a thick cartilaginous wall which is continuous with the parachordal cartilage and seems to take the place of that cartilage as a part of the general cranial wall.

While the base of the cranium, to the extent already mentioned, is cartilaginous in its origin, the lateral and upper walls are chiefly of membranous formation, as in the squama occipitis, the squamo-zygomatic of the temporal, the parietal and the frontal bones.

The membranous tissue in which these flat bones of the cranial vault are formed is regarded by Kölliker as of dermal origin, and the bones as belonging to the group of investing bones. Their formation is however in part supplemented by the extension upon them from below of a plate of cartilage which is placed internally to the membranous matrix.

The trabeculæ stretch forward to the anterior extremity of the head, and maintain the foremost place in the seat of the nasal cartilages and external apertures of the nose. Behind these the coalesced trabeculæ form a narrow ethmo-vomerine cartilage, the nasal septum, round the back of which the vomer is formed as a bony splent covering; while in the hinder lyre-shaped interval of the separated trabeculæ is placed the infundibulum in connection with the pituitary body.

Fig. 708.

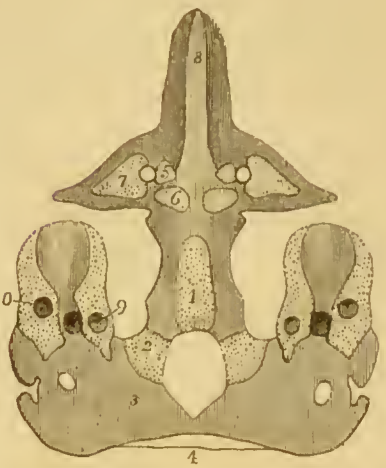


Fig. 708.—View from below of the cartilaginous base of the cranium with its ossific centres in a human fœtus of about four months. (From Huxley, slightly altered.)

The bone is dotted to distinguish it from the cartilage, which is shaded with lines. 1, the basilar part, 2, the condyloid or lateral parts, and 3, 4, the tabular or superior part of the occipital surrounding the foramen magnum; 5, centres of the presphenoid on the inside of the optic foramen; 6, centres of the post-sphenoid; 7, centres of the lesser wings or orbito-sphenoid; 8, septal cartilage of the nose; 9 and 10, parts of the labyrinth.

From the side of the presphenoid cartilage the matrix of the orbito-sphenoids or lesser wings, containing the optic foramina, is developed: and from the sides of the basi-sphenoid proceeds the matrix of the greater wings, which are also cartilaginous in their origin.

In the periotic or cartilaginous rudiment of the temporal bone three centres of formation are distinguished by Huxley, viz.: 1. *Opisthotic*, or that surrounding the fenestra rotunda and cochlea; 2, *prootic*, or that which encloses the superior semicircular canal; and 3, *epiotic*, or that which surrounds the posterior semicircular canal and extends into the mastoid portion. They soon unite into one so as to form the petromastoid bone.

Fig. 709.

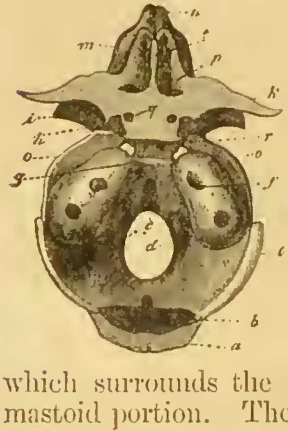


Fig. 709.—Basilar part of the primordial cranium of a human fœtus of three months, seen from above. (From Kölliker.)

a, upper half of the squama occipitis; *b*, lower half of the same; *c*, cartilaginous plate extending into it; *d*, (in the foramen magnum) the exoccipital; *e*, basi-occipital; *f*, petrous, with the meatus auditorius internus; *g*, dorsum sellæ, with two nuclei belonging to the basi-sphenoid bone; *h*, nuclei in the anterior clinoid processes; *i*, great wing nearly entirely ossified; *k*, small wings; *l*, crista galli; *m*, cribrethmoid; *n*, cartilaginous nose; *o*, strip of cartilage between the sphenoid and the parietal; *p*, osseous plate between the lesser wings and the cribriform plate.

Here it may be stated that, in addition to the parts of the skull before-mentioned, the ethmo-turbinals and cribriform plate, the styloid process and the three auditory ossicles are of cartilaginous origin; but the tympanic ring, the nasal, maxillary and other facial bones are all formed in membrane. To these, however, we shall recur hereafter.

In the cranium of the human embryo chondrification begins in the basilar portion in the fourth and fifth weeks, and is nearly completed for the principal parts by the eighth week, soon after which in the course of the tenth week cartilaginous ossification sets in. But in some of the membrane bones, as for example in the lower jaw, ossification begins at a much earlier date, probably in the sixth week.

The form of the head is greatly modified at an early period of development by the cranial flexure as well as by the changes which accompany the development of new parts.

The Cranial Flexures.—The earliest and the most important of the cranial flexures is that, previously mentioned, which takes place at the anterior extremity of the notochord and in the region of the mid-brain or middle encephalic vesicle. At this place the medullary tube, and the substance forming the wall of the cranium especially, undergo a sudden bending downwards and forwards, so as to cause the projection of the thickened cranial base in a marked manner upwards. This coincides with the place where the parachordals and the trabeculæ meet, and where inferiorly the pituitary body, and superiorly the infundibulum come into close relation.

Fig. 710.

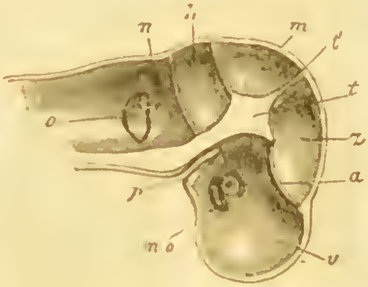


Fig. 710.—LONGITUDINAL SECTION THROUGH THE HEAD OF AN EMBRYO OF FOUR WEEKS. (From Kölliker.) $\frac{10}{1}$.

v, anterior encephalic vesicle, cerebral portion; *z*, inter-brain; *m*, mid-brain; *h*, cerebellum; *n*, medulla oblongata; *no* and *a*, optic vesicle: *o*, auditory depression; *t*, centre of basi-cranial flexure; *t'*, lateral and hinder parts of tentorium; *p*, the fold of epiblast which forms the hypophysis cerebri.

Above and behind this, the mid-brain gives greatest prominence to the part of the cranium occupied by it, a feature which remains characteristic of the embryo head for a considerable time.

The great cranial flexure thus marks the division between the strictly basi-cranial, or occipito-sphenoidal, and the basi-facial, or spheno-ethmoidal part, the chorda terminating between those two portions of the cranial base, with a thinner pointed part. Here the end of the chorda is bent downwards and forwards, and terminates in the post-sphenoid body, at the dorsum sellæ.

Other flexures also occur in connection with the development of the brain, but these do not affect materially the external form of the head. In man and the higher mammals the greatest modification of that form results primarily from the expansion of the cerebral hemispheres, and secondarily from the formation and proportional increase in the size of the jaws and other parts of the face.

1. **The Face.**—The formation of the facial part of the head takes place superficially by the downward and forward growth from the front and base of the simple cranium of the median *fronto-nasal* and the lateral *maxillary and mandibular* plates, and more deeply by the development of parts in connection with the cranio-facial axis, which is formed by the spheno-ethmoid extension of the trabeculæ

cranii. These formative changes are of a very complex kind, and comprehend the production of the external nose, the lips and cheeks, the jaws and palate, the deeper nasal fossæ and their labyrinth, the buccal cavity and the orbits, the auricle, auditory meatus and tympano-Eustachian passages, together with the various cavities of the bones in communication with the involuted nasal passages, such as the ethmoid, maxillary, sphenoid and frontal sinuses.

These parts all arise mainly in mesoblastic tissue, but are covered externally by epiblast, or are lined internally by that layer, excepting the tympano-Eustachian passage, which has a hypoblastic lining. The basi-facial axis is at first necessarily very short, as it lies only below the undeveloped first cerebral vesicle, but it speedily assumes greater proportions as it is elongated forward with the enlargement of the cerebral hemispheres and the simultaneous development of the nasal and buccal fossæ.

The nasal fossæ take their origin in the form of two simple depressions, the *primary olfactory* or *nasal pits*, which appear on the lower surface of the wall of the anterior cerebral vesicle at a very early period when no other parts of the face have yet been formed. But the trabecular part of the cranial wall, now extending forwards and doubling itself at its anterior extremity, curves round both the nasal pits from the inside and above, so as to cover them in some sort with a dome (Parker), in connection with which are afterwards formed the forepart of the septum and the lateral nasal cartilages. The nasal pits have at first no connection with the mouth, which forms a transverse depression in the lower and hinder part of the future face; but later, or by the fifth week in the human embryo, these cavities are brought into communication by the formation of the nasal grooves which run backwards one from each olfactory pit into the mouth, and at the same time the nasal fossæ begin to extend themselves upwards as narrow passages on each side of the enlarging septum, the lower part of the fossæ being still left in open communication with the buccal cavity.

Fig. 711.

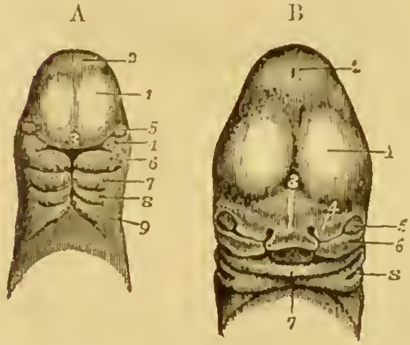


Fig. 711.—CRANIUM AND FACE OF THE HUMAN EMBRYO, SEEN FROM BEFORE. (From Ecker.)

A, from an embryo of about three weeks: 1, anterior cerebral vesicles and cerebral hemispheres; 2, inter-brain; 3, middle or fronto-nasal process; 4, superior maxillary plate; 5, the eye; 6, inferior maxillary or mandibular plate (first postoral); 7, second plate; 8, third; 9, fourth, and behind each of these four plates their respective pharyngeal clefts. B, from an embryo of five weeks: 1, 2, 3, and 5, the same as in A; 4, the external nasal or lateral frontal process; 6, the superior maxillary plate; 7, the mandibular; ×, the tongue; 8, the first pharyngeal cleft, which becomes the auditory passage.

Fronto-nasal Plate.—The external nose owes its origin to the development of the fronto-nasal plate, previously mentioned, which forms a broad median lappet in the fifth and sixth weeks of the human embryo, descending from the front of the cranium between the two large ocular vesicles as far as the transverse buccal cleft. It is free in front and inferiorly, but behind it is in union with the parts developed from the trabecular axis. Its lower border encloses the nasal pits which come to form deep notches in it, and it is thus divided into a median and two lateral nasal processes. The central division forms the prominent part of the future nose with its *columella* below, and its further prolongation downwards gives rise to the *lunula* or central part of the upper lip; while the parts outside the nasal notches, *the external nasal processes*, receding somewhat, reach the orbital fissure, and are the source, later, of the alæ of the nose.

The further development of the nose consists mainly in the formation of the deeper parts, such as the septum, cribriform plates, and the labyrinth or turbinal portions, which will be noticed in connection with the olfactory organ. Here we have only to do with its relation to the face and mouth.

The Mouth.—The buccal cavity arises as a wide cleft or depression in the lower part of the face, having above it the fronto-nasal process in the middle, and the superior maxillary processes on each side, and below it the first pair of visceral arches or mandibular plates, which meet each other in the middle, and are continuous round the outer angles of the mouth with the maxillary processes: the deepening of the buccal cavity itself being mainly due to the outward development of these several processes.

Fig. 712.

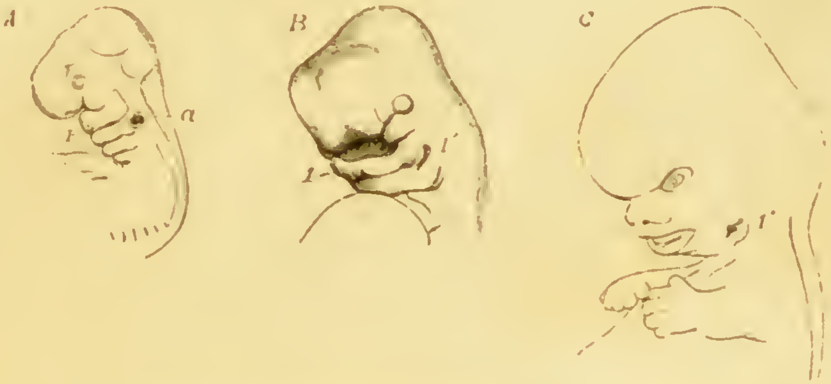


Fig. 712.—OUTLINES SHOWING THE EARLY CHANGES IN THE FORM OF THE HEAD OF THE HUMAN EMBRYO.

A, profile view of the head and fore part of the body of an embryo of about four weeks (from nature, $\frac{10}{1}$): *a*, the auditory vesicle; 1, mandibular arch, and behind this are seen the three following arches with the corresponding pharyngeal clefts. *B*, embryo of about six weeks (from Ecker, $\frac{5}{1}$): 1, the lower jaw: 1′, the first pharyngeal cleft, now widening at the dorsal end, where it forms the meatus externus; the second cleft is still visible, but the third and fourth clefts are closed and the corresponding plates have nearly disappeared. *C*, from a human fœtus of nine weeks (from nature, $\frac{3}{1}$); the features of the face are now roughly formed; the meatus is forming in the dorsal end of the first pharyngeal cleft, and the auricle is beginning to rise from its outer border.

The primitive mouth (*stomodæum*) is therefore lined entirely by epiblast, and is separated from the fore-end of the pharynx by this layer, as well as by the inflection of the visceral mesoblast and the hypoblast which close that cavity anteriorly. The establishment of a communication between the mouth and pharynx by the wearing through of the several blastodermic layers named, in the form at first of a vertical slit, takes place on the fifth day in the chick, and probably at the eighth or ninth week in the human embryo. To this change, which gives rise to the aperture of the fauces, reference will again be made in the history of the development of the alimentary canal. From what has been said previously, it is apparent that the upper lip is formed in part by the fronto-nasal and maxillary plates which are at first separated by the orbital fissures, and that the lower lip is a part of the mandibular plates. The integrity of the upper lip is established by the inward advance of the superficial part of the lateral maxillary processes, which, coalescing with both the internal and external nasal processes, close in the nasal notches inferiorly as the nostrils, and obliterate in great part the orbital fissures, leaving only more deeply within them the lachrymal canals or nasal ducts. While the upper lip is thus completed superficially, a deeper development and union of the maxillary and intermaxillary matrices occurs, which leads to the completion of the alveolar arch.

Fig. 713.

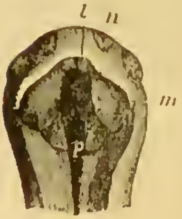


Fig. 713.—HEAD OF HUMAN EMBRYO OF EIGHT WEEKS, SEEN FROM BELOW, THE LOWER JAW HAVING BEEN REMOVED. $\frac{4}{1}$. (From Kölliker.)

n, the external nasal apertures; *i*, premaxillary process, and outside this the internal nasal aperture; *m*, palatal process advancing from the side to form the partition between mouth and nose; *p*, common cavity of the nose, mouth and pharynx.

The separation of the cavity of the mouth strictly so called from the nasal fossæ, is effected by the development of the palatal or pterygo-palatal processes of the maxillary plate, which advancing inwards from the two sides meet and coalesce with each other and with the septum descending from above in the middle line. But this median union does not in the same form extend to the anterior part which is occupied by the intermaxillary process; for here the maxillo-intermaxillary cleft is double, and, when the union of the opposite parts takes place, the naso-palatine canal is left as the vestige of the previous fissures.

Fig. 714.

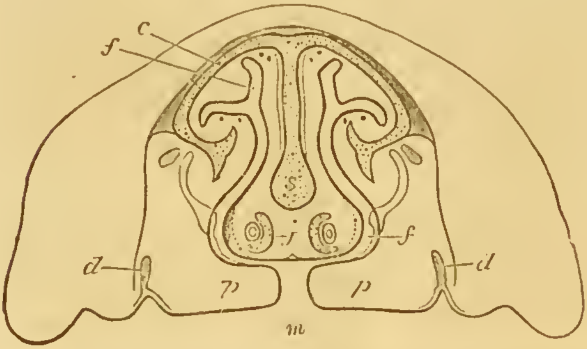


Fig. 714.—OUTLINE OF A TRANSVERSE VERTICAL SECTION THROUGH THE NOSE AND UPPER JAWS OF A SHEEP'S EMBRYO WITH OPEN PALATE. (From Kölliker) slightly magnified.

The lower jaw and tongue are removed; *m*, the mouth; *d*, dental germs; *p*, the palate plates approaching each other in the middle; *f*, the nasal fossæ; *c*, nasal cartilage; *s*, septal cartilage; *j*, the two organs of Jacobson with their cartilages internally.

The median union of the palate begins in front about the eighth week in the human embryo, and reaches the back part, when completed, in the ninth and tenth weeks. There are thus formed the hard and soft palates as the floor of the lower or respiratory part of the nasal fossæ, leading posteriorly into the pharynx, and the roof of the proper buccal cavity. The malformations of double hare-lip and maxillo-intermaxillary clefts, which usually accompany it on one or both sides, together with that of the single or median cleft palate in its various degrees, receive an interesting explanation from the study of the developmental phenomena now referred to.

It is in connection with the lower part of the septum and intermaxillary plate that there are found at an early period in the human embryo as well as in that of other mammals the rudiments of the **Organ of Jacobson** and the inferior internal nasal cartilages which surround them externally (see fig. 714).

It may further be mentioned at this place that from the roof of the mouth at a very early period, as by the third or fourth week in the human embryo, there is formed the diverticulum lined by epiblast, which in its combination with the infundibulum and farther development, gives rise to the pituitary body (see later, p. 831).

In the superficial part of the maxillary plates are formed the superior maxillary and malar as membrane or investing bones, and on the inside of the orbit in connection with the nasal duct the lachrymal bones.

There is a marked difference between the bones which arise in connection with the trabeculæ, such as the pre-sphenoid, orbito-sphenoid, septal ethmoid, cribriform and ethmo-turbinal, which have all cartilaginous matrices, and those which are of membranous origin and have an investing character, such as the nasal, lachrymal, vomer, internal pterygoid, palatal, superior maxillary, malar and mandibular bones of the face. It is, however, an interesting fact (Kölliker) that the various sinuses which come to occupy places within some of the cranial and facial bones, such as the ethmoid, maxillary, sphenoid and frontal, all arise by extension of the epiblastic lining of the nasal passages, and are preceded by the formation of cartilaginous capsules, within each of which the epiblastic extension is situated, and that these epiblastic and cartilaginous capsules make their way gradually into the interior of the respective bones afterwards occupied by the sinuses, the bones being gradually hollowed out by absorption to receive them. In this process the ethmoid sinuses are the earliest to be formed, beginning at the sixth month in the human embryo; the maxillary follow very soon, or nearly at the same stage, but continue to grow for a long time. The sinuses do not penetrate the sphenoid till about the seventh year, having peculiar relations with the bones of Bertin (see vol. I., p. 72), and the frontal sinuses are the latest in appearing, not having made much progress till the age of puberty, when they expand rapidly, and when also all the others undergo a greater extension.

2. **Postoral Visceral Arches—Branchial Arches.**—The formation of the lateral and lower parts of the face, including the mouth and lower jaws, the hyoid apparatus, the auricles and tympano-Eustachian passages, is intimately connected with the development of the subcranial pairs of processes which are most appropriately named the *Visceral Arches*, as enclosing the mouth and the anterior or pharyngeal portion of the primary alimentary cavity. The visceral arches now referred to were first described by Rathke in 1825, (No. 173,) and from their general homology with the arches of the gills in aquatic animals were named by him the branchial arches. Their development was subsequently very fully investigated by Reichert (1837, No. 174).

In the amniota the postoral visceral arches are four, or, according to some, five in number. The first or anterior of these plates, which forms the posterior margin of the mouth, and is named *mandibular*, is the seat of formation of the lower jaw: the second, named *hyoid*, gives origin in part to the hyoid apparatus; the third arch, in which the remainder of the hyoid bone is formed, and which may be named *thyro-hyoid*, corresponds to the first of those which in aquatic animals undergoes full branchial development, but which in the amniota, like the two following it, never bears gills.

The fourth and fifth arches have no special names, but might be termed post-hyoid or cervical, as being situated in the place where the elongation of the neck occurs at a later period,—a process which gives rise to some of the peculiar features familiar to anatomists as characterising the parts occupying the cervical region.

Visceral Clefts.—Behind each of these visceral arches there is placed on each side a cleft which runs through the wall of the body from the external surface into the cavity of the pharynx, thus bringing epiblast and hypoblast into continuity. The first of these clefts, which from its position may be named *hyo-mandibular*, is afterwards the seat of the formation of the Eustachian passage and cavity of the tympanum internally, while the meatus auditorius is developed externally round the dorsal part of the cleft by the outgrowth of the neighbouring parts of the two arches; the membrana tympani growing up between them. The external auricle is developed from the integument behind the meatus. The three remaining clefts, which represent branchial apertures of aquatic animals, are all closed in the amniota at an early period, corresponding to the sixth or seventh week in the human embryo.

Fig. 715.

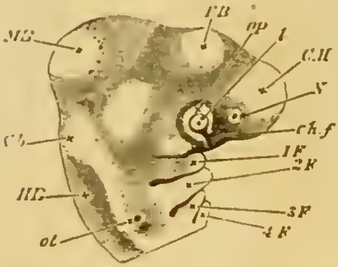


Fig. 715.—Side view of the head of an embryo-chick of the third day. (From Balfour.)

CH, cerebral hemispheres; *FB*, vesicle of the third ventricle; *MB*, mid-brain; *Cb*, cerebellum; *HB*, medulla oblongata; *N*, nasal pit; *ot*, auditory vesicle not yet closed externally; *op*, optic vesicle, with *l*, the lens, and *ch.f*, the orbital fissure (in mesoblast); 1*F*, the first visceral fold or plate, the superior maxillary fold slightly indicated above it; 2, 3, 4*F*, the second, third, and fourth visceral plates with the visceral clefts between them.

In some of the lower vertebrates, as in the elasmobranchs and cyclostomes, the hinder branchial arches are more numerous than in other animals, and in some the hyoid arch possesses a developed gill. In aquatic animals generally the gill arches have cartilaginous bars, but in man and mammals it is only in the three first visceral arches, that is, the mandibular, hyoid and thyro-hyoid, that cartilaginous bars are formed.

Through each of the visceral arches there runs a considerable arterial vessel, which is one of the five pairs of vascular arches formed by the division of the aortic bulb, and which in the embryoes of amniota reunite dorsally, without subdivision into branchial vessels, to form the aorta (see Vascular System, p. 868).

It is an interesting fact stated by Balfour that in the early stages of development of the branchial plates in elasmobranchs there is in the outer part of each of them a cavity extending from the ventral to the dorsal ends, which he regards as having been derived by extension from the general body-cavity in the same manner as occurs in the vertebral somites of the trunk of the body; and further that muscle-plates are formed round these head cavities, which probably furnish the rudiments of a certain number of the head muscles.

Farther Destination of the Visceral Arches.—Some of the remaining facts respecting the development of the visceral arches will be most conveniently described along with those relating to the formation of the ear and other organs with which they are associated. Here it will be sufficient to state shortly the principal destination of each of them,

The cartilage of the first or mandibular visceral arch has long been known as the *cartilage of Meckel*, which occupies the deeper part of the arch from a very early period, and, attaining considerable size, remains visible in the human fœtus up to the sixth or seventh month. Its proximal portion is now known to be converted into the *malleus* of mammals, and into the homologous *quadrate* bone of reptiles and birds.

In mammals the lower jaw, corresponding mainly with the dentary bone of other animals, is developed at a very early period first from membrane outside Meckel's cartilage; but it is also partially incorporated with those cartilages at their lower or distal part where they meet each other in the symphysis. A part of Meckel's Cartilage between the jaw and the malleus is converted into the so-called internal lateral ligament of the jaw.

Fig. 716.

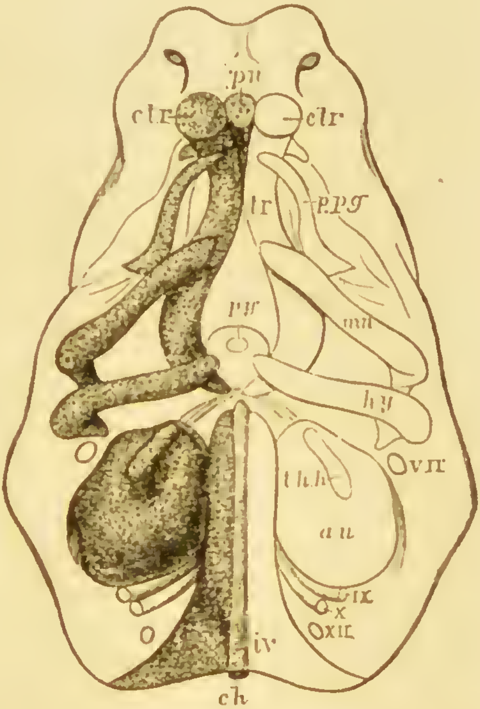


Fig. 716.—PLAN OF THE SKULL, &c., OF THE EMBRYO PIG, SEEN FROM BELOW. Magnified ten diameters. (From Parker.)

tr, cartilage of the trabeculæ: *ctr*, cornua trabecularum; *pn*, prenasal cartilage; *ppg*, pterygo-palatine cartilage; *mn*, the mandibular arch with Meckel's cartilage; *au*, the auditory vesicle; *hy*, the cerato-hyoid arch; *thh*, the thyro-hyoid; *py*, the pituitary fossa; *ch*, the notochord in the cranial basis, surrounded by the parachordals (*iv*): VII, facial nerve; IX, glosso-pharyngeal; X, pneumogastric; XII, hypoglossal nerve.

The second or hyoid visceral arch is originally closely united with the first arch at its cranial extremity below the auditory capsule. It contains in its proximal part the cartilaginous matrix of the incus, which becomes articulated with the head of the malleus formed in the adjacent proximal part of the mandibular arch. The remainder of this cartilaginous bar forms the tympano-hyal and styloid processes, the stylohyoid ligament, and the lesser wings of the hyoid bone (cerato-hyal).

The third visceral arch or thyro-hyoid gives rise, by its cartilaginous matrix, to the great wings and body of the hyoid bone. It supports the rudiment of the thyroid cartilage, and is closely connected with the development of the larynx.

The fourth and fifth arches, as already remarked, may be considered as belonging to the neck rather than to the head. The congenital fissures of the neck which have been observed as a malformation, and which usually open externally far down in that region, may be due to the persistence of one or more of the branchial clefts, much drawn out by the cervical elongation.

The tongue is formed, according to Kölliker, in connection with the three first visceral arches, but mainly with the mandibular. Its covering is derived from the epiblast of the mouth, its muscular substance probably proceeds from the muscle-plates of the visceral arches, and it rests by its base on the mesial process of the third arch, the basihyoid element.

Fig. 717.

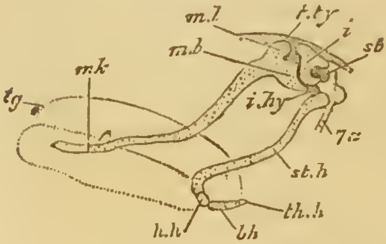


Fig. 717.—SIDE VIEW OF THE MANDIBULAR AND HYOID ARCHES IN AN EMBRYO PIG OF $1\frac{1}{3}$ INCH IN LENGTH. (From Balfour, after Parker.)

tg, tongue; *mk*, Meckel's cartilage; *ml*, body of malleus; *mb*, its manubrium or handle; *t.ty*, tegmen tympani; *i*, incus; *st*, stapes; *i.hy*, inter-hyal ligament; *st.h*, stylo-hyal cartilage; *h.h*, hypohyal; *bh*, basibranchial; *th.h*, rudiment of first branchial arch; *7a*, facial nerve. See also fig. 745, p. 839.

Relation of Developmental Facts to the Morphology of the Head.— It may be freely admitted that there is no primary segmentation of the formative elements of the head similar to the division of the vertebral or mesoblastic somites of the trunk; and yet there are not wanting proofs that the development of the head takes place in its earlier phases on essentially the same plan, and from the same blastodermic elements as the axial part of the trunk; while there are also sufficient grounds for recognising in the later stages of the formation of the cartilaginous matrices, and in the ossification of the bones, indications of some degree of segmentation of the cranial and facial elements.

These indications are to be found mainly in 1, the prolongation of the notochord and its parachordal investment from the vertebral axis of the trunk into the cranial base; 2, the enlargements of the notochord at certain places corresponding with the later separation of the bones; 3, the division of the visceral arches and the extension of the body cavity into their substance, together with the formation of muscle-plates in each of them; 4, the general similarity in the relations of the cranial and facial bases and the neural arches to the nervous centre and the issue of the nerves on the one hand, and of all these to the visceral or alimentary cavity on the other. But while these considerations would seem to indicate a morphological correspondence between cephalic and vertebral rudiments, much is still wanting to fill up the details of the comparison between them; and, admitting the serial homology to exist, the number of metameric somites or divisions of the head is not as yet by any means determined.

II. DEVELOPMENT OF THE NERVOUS SYSTEM.

It is one of the most important generalisations resulting from modern embryological inquiry, as has been well remarked by Balfour, that all the organs of the nervous system take their origin from the epiblast, or from the same source as the cuticular covering of the body. And this fact is not confined to vertebrate animals, but is universal throughout the whole of the Metazoa.

I. THE CEREBRO-SPINAL CENTRE.

In Vertebrates the first of these organs to appear is the great nervous centre comprising the brain and spinal cord in their primary rudimentary form of a simple medullary tube (as previously stated at p. 749); and it is now ascertained that while the central organs are produced by an involution and rapid growth of the epiblast in the line of the vertebral axis of the body, the roots and part at least of the peripheral nerves are developed by secondary extension from the primary medullary centre.

Fig. 718.

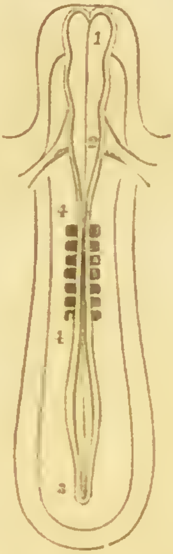


Fig. 718. Outline from above of the embryo chick in the first half of the second day.

1 to 2, the three primary encephalic vesicles enclosed in front and at the sides by the cephalic fold; 3, the hinder extremity of the medullary canal dilated into a rhomboid space in which is the primitive trace; 4, 4, seven proto-vertebral somites.

Fig. 719.

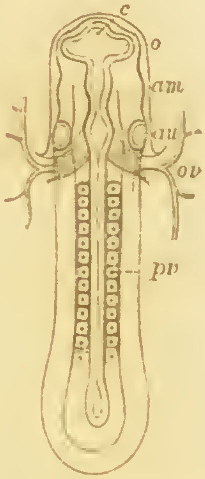


Fig. 719.—Embryo of the dog more advanced, seen from above. (After Bischoff.)

The medullary canal is now closed in; *c*, the anterior encephalic vesicle; *o*, the primitive optic vesicle; *au*, the primitive auditory vesicle opposite the third encephalic vesicle; *am*, the cephalic fold of the amnion; *ov*, the vitelline veins entering the heart posteriorly; *pv*, the proto-vertebral somites.

But it is not yet fully ascertained whether the whole of the peripheral nerves are derived from this source or are formed by secondary differentiation from blastema in the more remote seats of their origin.

From what has been previously stated it will have been seen that the rudiment of the cerebro-spinal nervous centre is formed more immediately from the thickened medullary plates of the involuted epiblast, the ridges of which, rising from the surface of the blastoderm, become united dorsally along the middle line so as to close in a hollow medullary tube of a cylindrical form. This tube is wider at its anterior or cephalic extremity, and this dilated portion becomes divided by partial constrictions, first into two, and very soon after into three *primary cerebral or encephalic vesicles*, which represent anterior, middle and posterior primary divisions of the brain. The spinal portion retains a more uniform cylindrical shape, excepting towards the caudal extremity, where it is longer in being formed, and remains for a time a flat open rhomboidal dilatation. The continuous cavity enclosed within the primitive medullary tube is the same with that which, variously modi-

Fig. 720.

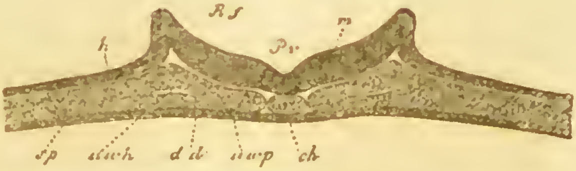


Fig. 720.—Transverse section through the embryo of the chick and blastoderm at the end of the first day. Magnified from 90 to 100 times. (From Kölliker.)

h, epiblast; *dd*, hypoblast; *sp*, mesoblast; *Pr*, medullary groove: *m*, medullary plates; *ch*, chorda dorsalis; *uvp*, proto-vertebral plate; *uwh*, commencement of division of mesoblast into its upper and lower laminæ; between *Rf* and *h* the dorsal laminæ or ridges which by their approximation close in the medullary canal.

fied, afterwards constitutes the central ventricles of the brain and canal of the spinal cord.

The formative cells composing the medullary substance are at first spherical, but they afterwards become elongated and spindle-shaped, and increase rapidly by multiplication. They represent at first the grey substance, or the nerve-cells and non-medullated fibres. The cylindrical cells which, from the first, line the whole canal, remain permanently in some parts of it, and frequently present the ciliated structure.

Fig. 721.

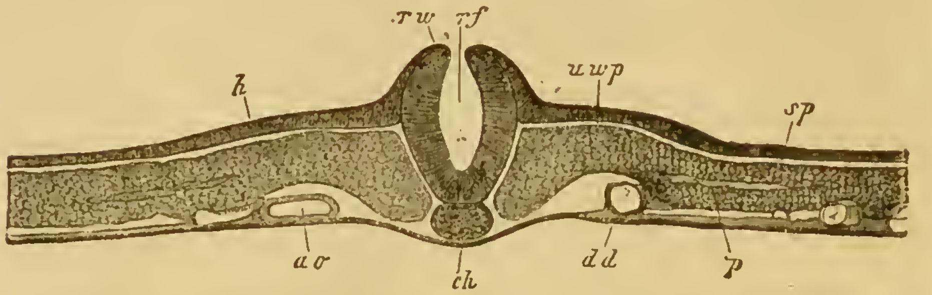


Fig. 721.—TRANSVERSE SECTION OF AN EMBRYO CHICK OF THE LATTER HALF OF THE SECOND DAY, AT THE PLACE WHERE THE VERTEBRAL SOMITES CEASE. $\frac{43}{1}$. (From Kölliker.)

rw, dorsal ridges; *rf*, medullary groove, or canal beginning to close; *uwp*, proto-vertebral plate; *sp*, lateral plate of the mesoblast; *h*, epiblast; *dd*, hypoblast; *ao*, primitive double aorta; *sp*, commencement of division of the mesoblast which forms the body-cavity.

Fig. 722.

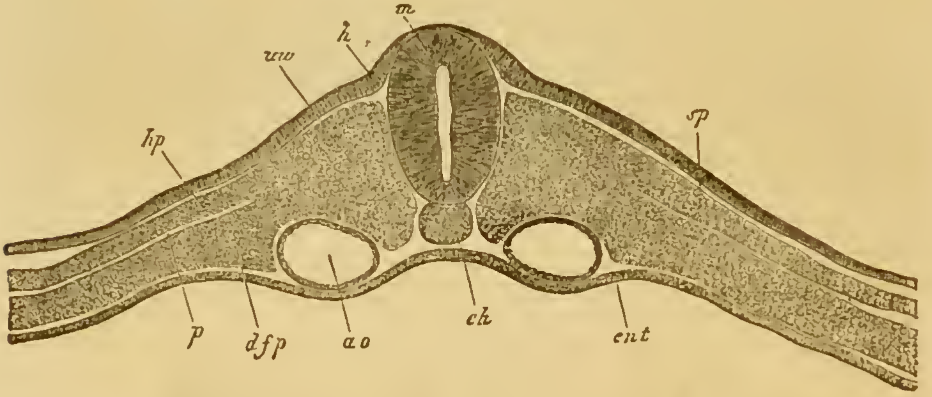


Fig. 722.—TRANSVERSE SECTION OF THE EMBRYO CHICK IN THE LATTER HALF OF THE SECOND DAY, IN THE REGION OF THE PROTO-VERTEBRÆ. $\frac{100}{1}$. (From Kölliker.)

m, medullary tube; *h*, epiblast now separated from the medullary inflection; *uw*, proto-vertebral mass; *hp*, parietal or somatic mesoblast; *dfp*, visceral mesoblast; *p*, pleuro-peritoneal or body-cavity between these two layers; *ch*, notochord; *ao*, aorta still double; *ent*, hypoblast.

THE SPINAL CORD.

The internal grey substance of the spinal cord is first formed; the white substance is produced later on the exterior. The sides acquire considerable increased thickness, while the dorsal and ventral parts remain comparatively thin, so that the cavity assumes in section the appearance of a slit, which becomes gradually narrower as the lateral thickening increases; and at last the opposite surfaces uniting in the middle divide the primary central canal into an anterior or lower and posterior or upper part (see figs. 724 and 725).

The lower of these divisions becomes the permanent central canal, the upper or dorsal is afterwards so far obliterated that it is filled with a septum of connective tissue belonging to the pia mater, and becomes the posterior fissure of the cord (in human anatomy) (Lockhart Clarke, No. 188).

In birds and mammals there is no distinction to be seen at first between the outer or corneous layer of the involuted epiblast and the cells which by their increase more immediately constitute the medullary plates. In batrachia, however, the dark colour of the corneous layer shows it to be distinct from a deeper layer which is the more strictly nervous. In Osseous fishes, and some other animals, there is no open medullary groove or canal at first, but an involution of a solid column of epiblast, which subsequently becomes hollow for the formation of a ventricular cavity.

Fig. 723.

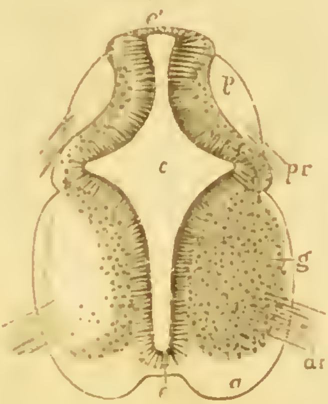


Fig. 723.—TRANSVERSE SECTION OF THE CERVICAL PART OF THE SPINAL CORD OF A HUMAN EMBRYO OF SIX WEEKS. (From Kolliker.) $\frac{30}{1}$

This and the following figure are only sketched, the white matter and a part of the grey not being shaded in. *c*, central canal; *e*, its epithelial lining, at *e* (inferiorly), the part which becomes the anterior commissure; at *é* (superiorly), the original place of closure of the canal; *a*, the white substance of the anterior columns, beginning to be separated from the grey matter of the interior, and extending round into the lateral column, where it is crossed by the line from *g*, which points to the grey substance; *p*, posterior column; *ar*, anterior roots; *pr*, posterior roots.

The masses of grey matter first formed in the spinal marrow correspond chiefly with the anterior columns. These are succeeded by lateral masses or columns, and somewhat later by small posterior columns. There are at first no commissures except by the passage of the deepest layer of cells across the middle line, but the fibres from the roots of the nerves when formed are traceable into the grey substance of their respective anterior and posterior columns.

The white substance is formed external to or on the surface of the deeper grey substance; but it is not yet determined whether it is wholly developed out of the cells composing the grey matter or from separate blastema to which the mesoblast may in part contribute. It is certainly combined with connective tissue elements, and its mode of formation is different from that of the grey substance, which is the more direct product of differentiation of the involuted epiblastic cells. How far the mesoblast takes part in the formation of the latter is still doubtful (see p. 192).

On the fifth and sixth days in the chick, according to Foster and Balfour, the white columns increase rapidly in size, and the anterior median fissure begins to be formed between the anterior columns by their swelling outwards and leaving its interval between them. It is at first wide and shallow, and soon receives a lining of vascular connective tissue or pia mater. The commissures are now also formed; the anterior grey commissure first, then the posterior grey, and somewhat later the anterior white commissure.

Fig. 724.

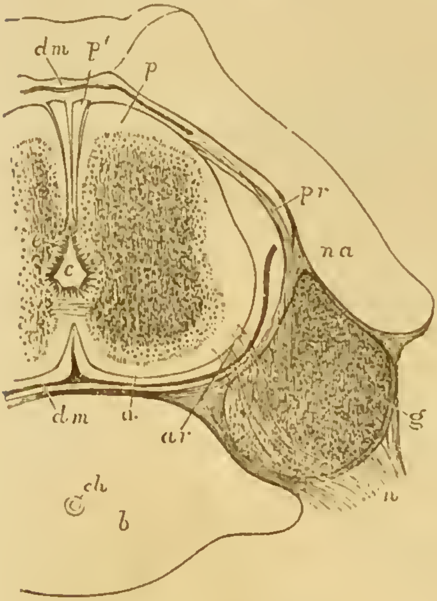


Fig. 724.—Transverse section of half the cartilaginous vertebral column and the spinal cord in the cervical part of a human embryo of from nine to ten weeks. (From Kölliker.) $\frac{10}{1}$

c, central canal lined with epithelium; *a*, anterior column; *p*, posterior column; *p'*, band of Goll; *g*, ganglion of the posterior root; *p r*, posterior root; *a r*, anterior root passing over the ganglion; *d m*, dura-matral sheath, omitted near *p r*, to show the posterior roots: *b*, body of the vertebra; *c h*, chorda dorsalis; *n a*, neural arch of the vertebra.

In the further increase of the anterior and lateral white columns as they thicken, they become more united together on each side, so that they can only be arbitrarily distinguished; the fibres of the roots of the nerves are traced through them into the grey matter; the cornua of grey matter become more and more developed, and the fissures between the white columns deepen, while the connective tissue or pia-matral septa run more completely inwards through the white substance.

Fig. 725.

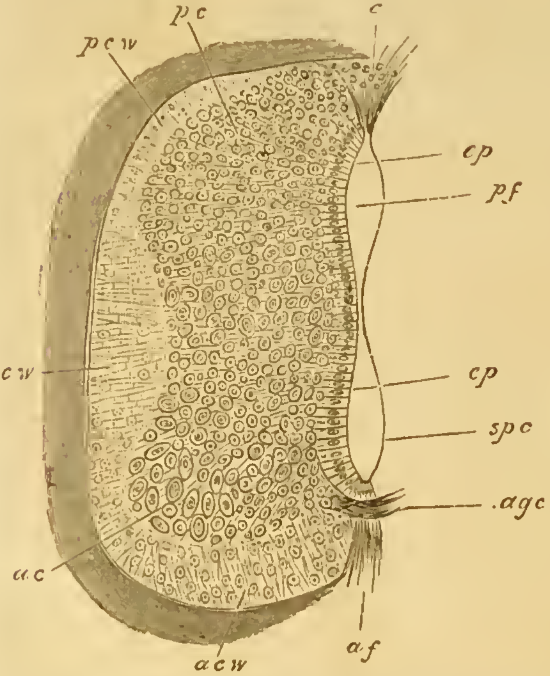


Fig. 725.—Transverse section of half of the spinal cord of the chick of seven days. (From Foster and Balfour.) Magnified.

pcw, posterior, *lcw*, lateral, and *acw*, anterior white columns; *pc*, posterior cornu of grey matter with small cells; *ac*, anterior grey cornu with large cells; *cp*, epithelium of the canal; *c*, the upper part now open and filled with tissue in the posterior fissure; *spc*, the lower division of the primitive medullary cavity, which remains as the permanent canal; *af*, anterior fissure left between the projecting anterior columns; *agc*, anterior grey commissure; *pf*, posterior fissure.

Angular cells with radiating processes make their appearance in the grey matter, and the nerve-fibres both of the grey and white matter become more distinct.

The cylindrical cells lining the central canal retain their distinctness, and they are more completely separated from the grey matter by the delicate tissue of the ependyma. Throughout the greater part of the spinal cord the dorsal part of the primary medullary hollow is obliterated to form the fissure, but in the sacral region of birds it opens out in the rhomboidal sinus, and in the filum terminale of the human cord the whole primary medullary cavity remains.

The SPINAL CORD has been found by Kölliker already in the form of a cylinder in the cervical region of a human embryo of four weeks. Ununited borders have been seen by Tiedemann in the ninth week towards the lower end of the cord, the perfect closing of the furrow being delayed in that part, which is slightly enlarged, and presents a longitudinal median slit, analogous to the rhomboidal sinus in birds.

The *anterior fissure* of the cord is developed very early, and contains even from the first a process of the pia mater developed from mesoblast.

The *cervical* and *lumbar enlargements*, opposite the attachments of the brachial and crural nerves, appear at the end of the third month : in these situations the central canal, at that time not filled up, is somewhat larger than elsewhere (see figs. 733 and 736).

At first the cord occupies the whole length of the vertebral canal, so that there is no cauda equina. In the fourth month the vertebræ begin to grow more rapidly than the cord, so that the latter seems as it were to have been retracted within the canal, and the elongation of the roots of the nerves which gives rise to the *cauda equina* is commenced. At the ninth month, the lower end of the cord is opposite the third lumbar vertebra. (Kölliker, Lockhart Clarke, Bidder und Kupffer, Foster and Balfour.)

The origin of the roots of the spinal nerves will be referred to later.

THE BRAIN OR ENCEPHALON.

1. *General phenomena of development as ascertained in birds and mammals.*—Reference has previously been made to the simple form in which the brain at first presents itself in the anterior dilated portion of the primitive medullary tube, and its partial division into the three primary cerebral vesicles. These primary vesicles are named fore-brain, mid-brain, and hind-brain, and correspond most nearly to the regions of the third ventricle, the corpora quadrigemina and the medulla oblongata of the adult brain.

The changes which mainly tend to modify the form of this primitive brain are, 1st, the development on each side from the anterior vesicle of the primitive ocular vesicle; 2nd, the protrusion somewhat later from the forepart of the anterior cerebral vesicle of a bulging part, at first single or undivided, but which by a median cleft and lateral expansion becomes later the rudiment of the two cerebral hemispheres; and 3rd, the formation in the forepart of the posterior vesicle of a new encephalic rudiment corresponding to the cerebellum. Thus the first vesicle becomes converted into the cerebral hemispheres and vesicle of the third ventricle or thalamencephalon, the middle vesicle remains undivided, and the hinder vesicle becomes the cerebellum and medulla oblongata.

The formation of the primitive ocular vesicles, by an evolution of the lateral wall of the primitive medullary tube, gives to the first vesicle and the adjacent part of the head a much greater lateral width; but the cranial wall, though pushed out by the enlarging ocular vesicles, does not follow closely the inflection of their surfaces. As the subsequent contraction of the stalk of the ocular vesicles progresses, these vesicles are thrown more backwards and downwards by the development of the cerebral vesicles.

Fig. 726.

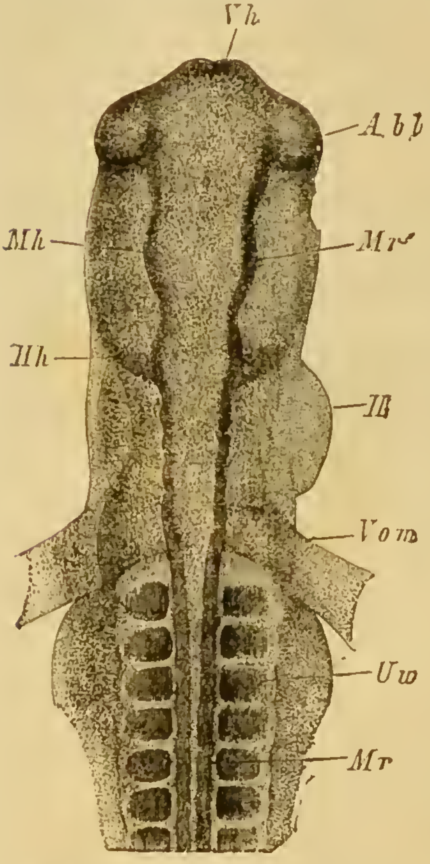


Fig. 726.—Fore-part of the embryo shown in fig. 689, viewed from the dorsal side. $\frac{70}{1}$. (From Kölliker.)

Vh, fore-brain ; *Abl*, ocular vesicles ; *Mh*, mid-brain ; *Hb*, hind-brain ; *H*, part of the heart seen bulging to the right side ; *Vom*, omphalo-mesenteric or vitelline veins entering the heart posteriorly ; *Mr*, medullary canal, spinal part ; *Mr'*, medullary wall of the mid-brain ; *Uw*, proto-vertebral somites.

As the cerebral vesicles become enlarged, the cranial wall undergoes a corresponding expansion in the forepart of the head, the cavities of the lateral ventricles extend into their interior, and the vesicle of the thalamencephalon, which was at first the foremost part of the embryo-head, is thrown backwards into a somewhat deeper position.

The middle encephalic vesicle, increasing greatly in size, takes the most prominent part of the head superiorly, both from its own greater relative magnitude, and from the sudden bend which the head now takes below this vesicle in the great cranial flexure.

The formation of the cerebellum begins by a thickening in the upper

Fig. 727.

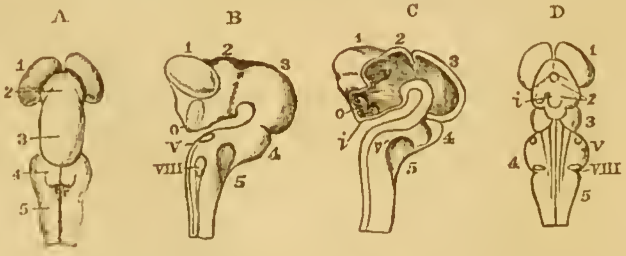


Fig. 727.—Four views of the brain of an embryo kitten in the stage of first division into the five cerebral rudiments, magnified three diameters. (From Reichert.)

A, from above ; B, from the side ; C, vertical section showing the interior ; D, from below.

1, Cerebral hemisphere, prosencephalon ; 2, thalamencephalon ; 3, mesencephalon, still single ; 4, cerebellum, epencephalon ; 5, myelencephalon, medulla oblongata ; *o*, optic nerves ; V, fifth pair ; VIII, eighth pair or glossopharyngeal and pneumogastric ; *i*, infundibulum ; *v*, *v'*, general ventricular cavity, opening at *v* into the lateral ventricle by the foramen of Monro.

and lateral walls of the part of the posterior primitive vesicle which is next to the mid-brain, and is accompanied by a deep inflection of the medullary tube between it and the remaining part of the vesicle which forms the medulla oblongata.

At the same time that these changes are progressing, two other remarkable phenomena occur, which, as presenting themselves very constantly in the brains of vertebrates, and having important morphological relations, may be mentioned at this place. These phenomena are both related to the thalamencephalon, and they consist, 1st, in the downward projection of a pointed funnel-shaped part of the cerebral wall, with a prolongation of the ventricular cavity within it, into the pituitary fossa, preparatory to its union with the evoluted part of the mouth cavity by which the pituitary gland takes its rise; and 2nd, in the thinning of the dorsal wall of the brain, and the prolongation of a part of that wall, which in the lower vertebrates reaches the cranial roof by a peculiar tubular extension, and is the homologue of the pineal gland.

Fig. 728.

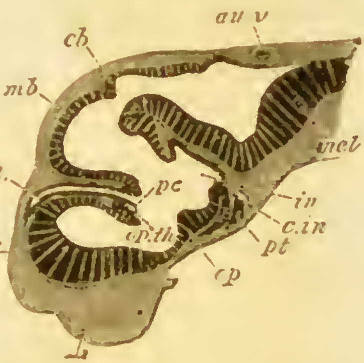


Fig. 728.—LONGITUDINAL SECTION THROUGH THE BRAIN OF SCYLLIUM CANICULA AT AN ADVANCED STAGE OF DEVELOPMENT. (From Balfour.)

cer, cerebral hemisphere; *pn*, pineal gland; *op.th*, optic thalamus; *op*, optic chiasma; *pt*, pituitary body; *in*, infundibulum; *cb*, cerebellum; *au.v*, recessus vestibuli, or passage from the auditory vesicle to the exterior; *md*, medulla oblongata; *c.in*, internal carotid artery.

There are thus distinguished the rudiments of five fundamental constituents of the brain, under which it will be found convenient to bring the notice of the development of the several parts forming the full-grown organ, and which may in this association be shortly enumerated as follows, viz.:—

Fig. 729.

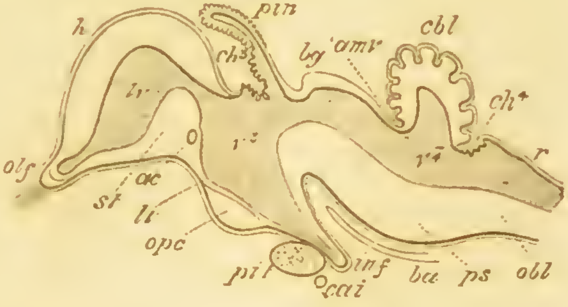


Fig. 729.—OUTLINE OF A LONGITUDINAL SECTION THROUGH THE BRAIN OF A CHICK OF TEN DAYS. (After Mihalkovics.)

h, cerebral hemisphere; *olf*, olfactory lobe and nerve; *st*, corpus striatum; *lv*, lateral ventricle; *ac*, anterior commissure; *lt*, lamina terminalis; *opc*, optic commissure; *pit*, pituitary gland; *inf*, infundibulum; *cai*, internal carotid artery; v^3, third ventricle; ch^3, choroid plexus of third ventricle; *pin*, pineal gland; *bg*, corpora bigemina; *amr*, anterior medullary velum; below which two last references are the aqueduct of Sylvius and crura cerebri; *cbl*, cerebellum; v^4, fourth ventricle; *ba*, basilar artery; *ps*, pons Varolii; ch^4, choroid plexus of the fourth ventricle; *obl*, medulla oblongata; *r*, roof of fourth ventricle.

1. The cerebral hemispheres, with their ventricular hollows or lateral

ventricles, the corpora striata, and the olfactory lobes,—a set of parts to which, as a whole, the name of *procerebrum* or *prosencephalon* may be given.

2. The *thalamencephalon* with its cavity or third ventricle, the primary ocular pedicles, and the infundibulum.

3. The *mesencephalon*, which is the same with the original middle vesicle, and comprises the corpora quadrigemina and crura cerebri with its contracted internal hollow, the iter a tertio ad quartum ventriculum of human anatomy.

4. The next part in succession is the *cerebellum*, along with which is included the pons Varolii and part of the fourth ventricle.

5. The hinder part, which passes into the spinal marrow, is the medulla oblongata, with the remainder of the fourth ventricle and its continuation into the central spinal canal.

Fig. 730.

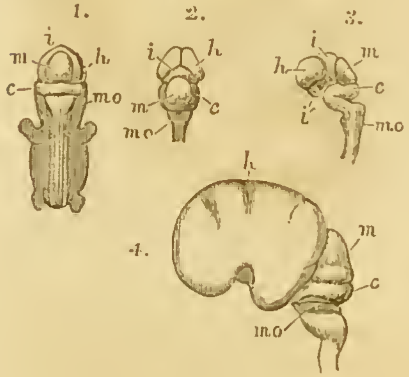


Fig. 730.—Sketches of the primitive parts of the human brain. (From Kölliker.)

1, 2, and 3 are from the human embryo of about seven weeks. 1, view of the whole embryo from behind, the brain and spinal cord exposed; 2, the posterior, and 3, the lateral view of the brain removed from the body; *h*, the cerebral hemisphere (prosencephalon); *i*, the thalamencephalon; *i'*, the infundibulum at the lower part of the same; *m*, the middle primary vesicle (mesencephalon); *c*, the cerebellum (epencephalon); *mo*, the medulla oblongata. Figure 3 shows also the several curves which take place in the development of the parts from the primitive medullary tube. In 4, a lateral view is given of the brain of a human embryo of three months: the enlargement of the cerebral hemisphere has covered in the optic thalami, leaving the tubercula quadrigemina, *m*, apparent.

In these five fundamental parts or rudiments of the brain, arising out of very simple modifications of the three primary encephalic vesicles, it is mainly by an increased thickening of the medullary wall in some of the parts, and the relative thinning, or even the entire removal of the substance in others, that the changes accompanying the formation of the cerebral masses are effected, while as a consequence of these and other modifications of form, the several parts of the internal cavity, or ventricles of the brain, acquire the different degrees of expansion and contraction, or the comparatively open or closed condition which they exhibit in after life. Thus the cerebral hemispheres and corpora striata are the main masses formed by the lateral thickening and expansion of the medullary walls of the procerebrum, while the corpus callosum and fornix are formed later by a deeper median development in connection with these parts: the thalami optici are the most solid parts of the lower and lateral region of the second rudiment: the corpora quadrigemina are thickenings of the upper wall of the third rudiment, while the crura cerebri arise by increased deposit in its lower part; the cerebellum may be regarded as a large deposit in the upper wall of the fourth rudiment, while the pons Varolii is a thickening of its lower wall; and the parts composing the medulla oblongata are principally formed by increased deposit in the lower and lateral wall of the fifth rudiment.

Thus, also, the lateral ventricles are two expansions of the forepart of the original ventricular cavity which result from the dilatation of the vesicles of the right and left cerebral hemispheres, and communicate with the central or third ventricle by the common foramen of Monro. The central or third ventricle, originally the foremost part of the medullary hollow, is narrowed on the sides by the increased development of the thalami optici, while inferiorly it is prolonged and projects downwards as infundibulum into the pituitary fossa; and on the upper side the wall of this ventricle comes to be opened up by the thinning away of its medullary substance, and otherwise modified in connection with the formation of the pineal gland. The continuation backwards of the original ventricular hollow, greatly narrowed by the ultimate thickening of the substance of the corpora quadrigemina and crura cerebri, forms the aqueduct of Sylvius, and is succeeded by the more expanded cavity of the fourth ventricle, lying between the cerebellum and the lower wall. The upper wall of the latter cavity undergoes great thinning like that of the third ventricle, so as to be reduced in the part before the cerebellum to the thin lamina forming the valve of Vieussens, and in the part behind it to be covered only by membrane, and to present an opening from the cavity into the posterior sub-arachnoid space.

Fig. 731.

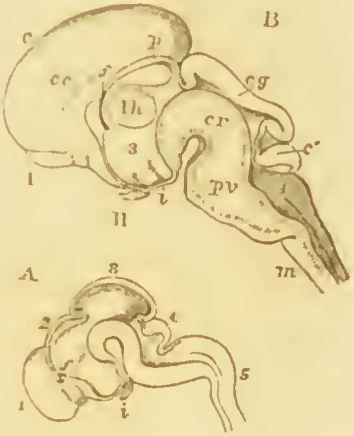


Fig. 731.—VERTICAL SECTIONS OF EMBRYONIC BRAINS IN TWO STAGES OF TRANSITION FROM THE RUDIMENTARY CONDITION, MAGNIFIED THREE DIAMETERS. (From Reichert.)

A, Brain of the embryo pig in commencing state of transition. 1, Right cerebral hemisphere: 2, thalamencephalon and position of the pineal gland; 3, mid-brain, with a large cavity; *f*, foramen of Monro; *i*, infundibulum; 4, cerebellum; 5, medulla oblongata.

B, Brain of the embryo of the cat, more advanced. *c*, Cerebral hemisphere passing backwards so as to cover the other parts; I, olfactory bulb; II, optic nerve; *th*, thalamus opticus; *f*, foramen of Monro; *cc*, corpus callosum; *p*, pineal gland; *i*, infundibulum; *cq*, corpora quadrigemina, not yet divided; 3, third ventricle; *cr*, crura cerebri, below the aqueduct of Sylvius, now reduced in width: *c'*, cerebellum; 4, fourth ventricle; *pv*, Pons Varolii; *m*, medulla oblongata.

Fig. 732.

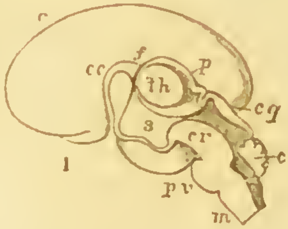


Fig. 732.—VERTICAL SECTION OF THE BRAIN OF A HUMAN EMBRYO OF FOURTEEN WEEKS, MAGNIFIED THREE DIAMETERS. (From Reichert.)

c, cerebral hemisphere; *cc*, corpus callosum beginning to pass back, *f*, foramen of Monro; *p*, membrane over the third ventricle and the pineal gland; *th*, thalamus opticus; 3, third ventricle: I, olfactory bulb; *cq*, corpora quadrigemina, mesencephalon; *cr*, crura cerebri, and above them the aqueduct of Sylvius still wide; *c'*, cerebellum, and below it the fourth ventricle; *pv*, Pons Varolii: *m*, medulla oblongata.

From what has before been said of the relation of the fundamental parts of the brain to the basis of the skull, it will be seen that the cerebral development is intimately connected also with the great cranial flexure which occurs at the pituitary fossa; for while the infundibular prolongation of the thalamencephalon projects down into this fossa, and the lamina terminalis lies in front in the position of the original foremost part of the encephalon, certain parts of the brain may be considered as situated posterior to this point, viz., the mesencephalon with crura cerebri, cerebellum with pons Varolii, and medulla oblongata, while the cerebral hemispheres, with the corpora striata, corpus callosum, and fornix, may be considered as formed in their earlier condition by forward expansion, and as situated in front of this turning point. But though the connections of the cerebral hemispheres with the rest of the brain may thus be regarded as anterior to the cranial centre, and while in their earlier stages, and still of small size, they are actually placed as in the lowest vertebrates entirely in front of it, yet by the later great proportional development in the higher animals, and especially in man, the cerebral hemispheres come to progress backwards, and successively to cover superiorly the thalami, corpora quadrigemina, the cerebellum, and the medulla oblongata.

The developmental relation of the several parts of the brain to its fundamental rudiments may be stated in the following tabular form:

I. Anterior primary Vesicle,	1. Prosencephalon.* Fore-brain.	Cerebral Hemispheres, Corpora Striata, Corpus Callosum, Fornix, Lateral Ventricles, Olfactory bulb (Rhinencephalon).
	2. Thalamencephalon. (Diencephalon.) Inter-brain.	Thalami Optici, Pineal gland, Pituitary body, Third Ventricle, Optic nerve (primarily).
II. Middle primary Vesicle,	3. Mesencephalon. Mid-brain.	Corpora Quadrigemina, Crura Cerebri, Aqueduct of Sylvius, Optic nerve (secondarily).
III. Posterior primary Vesicle.	4. Epencephalon. Hind-brain.	Cerebellum, Pons Varolii, anterior part of the Fourth Ventricle.
	5. Metencephalon. After-brain.	Medulla Oblongata, Fourth Ventricle, Auditory nerve.

(See the reference to works on the development of the brain under the Nos. 184—194.)

FARTHER DEVELOPMENT OF THE BRAIN IN MAN AND MAMMALS.

The full history of the development of the brain is so extensive and complicated a subject that it will be necessary to limit ourselves here to a very brief indication of the principal facts regarding it, proceeding from behind forwards in the order of the five fundamental parts of the brain above-mentioned.

1. Medulla Oblongata, Metencephalon, After-brain.—The medullary roof of this part becomes at an early period more and more widened out laterally, and reduced in thickness till at last scarcely any nervous substance remains, and the lateral parts, along with the inferior, thickening by the great increase of the medullary tissue, are thrown towards the side, and thus give rise to the wide space which forms the fourth ventricle, bounded posteriorly by the narrowing calamus scriptorius, and leading at its point into the canal of the spinal marrow. There is subsequently formed in the roof the opening which leads from the fourth ventricle into the subarachnoid space, and the pia mater, rich in blood-vessels, becomes folded over the roof and forms the plexus known as the choroid of the fourth ventricle.

The three more solid constituent parts of the medulla oblongata begin to be distinguishable about the third month; first the *restiform* bodies, which are connected with the commencing cerebellum, and afterwards the anterior pyramids and olives. The *anterior pyramids* become prominent on the surface and distinctly defined in the fifth month; and by this time also their decussation is evident. The *olivary* fasciculi are early distinguishable, but the proper *olivary body*, or tubercle, does not appear till about the sixth month. The *fasciolæ cinereæ* of the fourth ventricle can be seen at the fourth or fifth month, but the *white striæ* not until after birth.

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* This and the four following terms are adopted as applicable to the principal secondary divisions of the primary medullary tube, and as corresponding to the commonly received names of the German embryologists, viz., Vorderhirn, Zwischenhirn, Mittelhirn, Hinterhirn, and Nachhirn, or their less used English translations, given above.

2. The Cerebellum, Epencephalon, Hind-brain.—In the human embryo the cerebellum exists at the end of the second month, as a thin medullary lamina, forming, as in many of the lower vertebrate animals, an arch behind the corpora quadrigemina across the wide primitive medullary tube.

According to Bischoff, the cerebellum does not commence, as was previously supposed, by two lateral plates which grow up and meet each other in the middle line: but a continuous deposit of nervous substance takes place across this part of the medullary tube, and closes it in at once. This layer of nervous matter, which is soon connected with the corpora restiformia, or inferior peduncles, increases gradually up to the fourth month. The middle lobe is the first formed, and remains for a considerable time the principal mass of the cerebellum. The lateral lobes follow, and there is seen about the fifth month a division of these into the subordinate lobes; at the sixth, these lobes send out *folia*, which are at first simple, but afterwards become subdivided. Moreover, the *hemispheres* of the cerebellum are now relatively larger than its median portion, or *worm*. In the seventh month the organ is more complete, and the *flocculus* and *posterior velum*, with the other parts of the inferior vermiform process, are now distinguishable, except the *amygdalæ*, which are later in appearing.

Fig. 733.

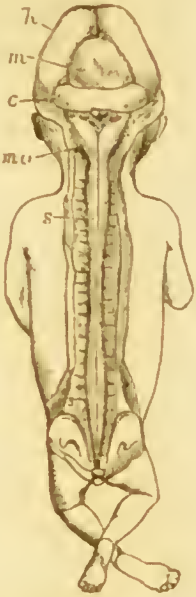


Fig. 733.—Brain and spinal cord exposed from behind in a fœtus of three months. (From Kölliker.)

h, the hemispheres; *m*, the mesencephalic vesicle or corpora quadrigemina, *c*, the cerebellum; below this are the medulla oblongata, *mo*, and fourth ventricle, with remains of the membrana obturatoria. The spinal cord, *s*, extends to the lower end of the sacral canal, and presents the brachial and crural enlargements.

Of the *peduncles* of the cerebellum, the *inferior* pair (corpora restiformia) are the first seen—viz., about the third month; the *middle* peduncles are perceptible in the fourth month; and at the fifth, the *superior* peduncles and the Vieussenian valve. The *pons Varolii* is formed, as it were, by the fibres from the hemispheres of the cerebellum embracing the pyramidal and olivary fasciculi of the medulla oblongata below. According to V. Baer, the bend which takes place at this part of the encephalon thrusts down a mass of nervous substance before any fibres can be seen; and in this substance transverse fibres, continuous with those of the cerebellum, are afterwards developed. From its relation to the cerebellar hemispheres the pons keeps pace with them in its growth; and, in conformity with this relation, its transverse fibres are few, or entirely wanting in those animals in which there is a corresponding deficiency or absence of the lateral parts of the cerebellum, as in marsupials and monotremes.

3. The Mesencephalon, Mid-brain.—The *corpora quadrigemina* are formed in the upper part of the middle cephalic vesicle; the hollow in the interior of which communicates with those of the first and third vesicles. The corpora quadrigemina, in the early condition of the human embryo, are of great proportionate volume, in harmony with what is seen in the lower vertebrata; but subsequently they do not grow so fast as the anterior parts of the encephalon, and are therefore soon overlaid by the cerebral hemispheres, which at the sixth month cover them completely. Moreover, they become gradually solid by the deposition of matter within them; and as, in the meantime, the *cerebral peduncles* are increasing rapidly in size in the floor of this middle cephalic vesicle, the cavity in its interior is quickly filled up, with the exception of the narrow passage named the *Sylvian aqueduct.* The fillet is distinguishable in the fourth month. The corpora quadrigemina of the two sides are not marked off from each other by a vertical median groove until about the sixth month; and the transverse depression separating the anterior and posterior pairs is first seen about the seventh month of intra-uterine life.

Fig. 734.

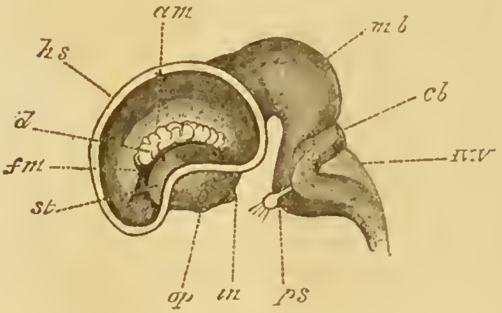


Fig. 734.—LATERAL VIEW OF THE BRAIN OF AN EMBRYO CALF OF 5 CM. (From Balfour, after Mihalkovics.)

The outer wall of the left hemisphere is removed to show the interior of the lateral ventricle; *hs*, cut wall of the hemisphere; *st*, corpus striatum; *am*, hippocampus major; *d*, choroid plexus of ventricle; *fm*, foramen of Monro; *op*, optic tract; *in*, infundibulum; *mb*, midbrain; *cb*, cerebellum; IV.V, roof of fourth ventricle; *ps*, pons Varolii; with fifth nerve and Gasserian ganglion.

The internal geniculate bodies belong to this division of the brain.

4. The Thalamencephalon, Inter-brain.—It is from this part, constituting at first the whole and subsequently the hinder part of the anterior primary encephalic vesicle, that the optic vesicles are developed in the earliest period, and the forepart is that in connection with which the cerebral hemispheres and accompanying parts are formed. The thalamus opticus of each side is formed by a lateral thickening of the medullary wall, while the interval between, descending towards the base, constitutes the cavity of the third ventricle with its prolongation in the infundibulum. The grey commissure afterwards stretches across the ventricular cavity. The medullary roof of this part on the other hand thins down rapidly, and is at last reduced only to a folded membrane, in connection with the pia mater of which the choroid plexus of the third ventricle is formed. The hinder part of the roof is developed by a peculiar process to be noticed later into the pineal gland, which remains united on each side by its pedicles to the thalamus, and behind these a transverse band is formed as posterior commissure.

Fig. 735.

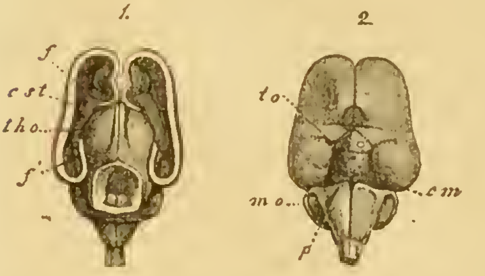


Fig. 735.—BRAIN OF THE HUMAN EMBRYO OF THREE MONTHS. NATURAL SIZE. (From Kölliker.)

In 1 the view is from above, the upper part of the cerebral hemispheres and mesencephalon having been removed. *f*, fore part of the divided wall of the hemisphere; *f'*, hind part of the same which becomes the hippocampus turned in; *cst*, corpus striatum; *tho*, thalamus opticus.

In 2 the lower surface is represented; *to*, tractus opticus; and in front of this the olfactory bulbs and tracts; *cm*, single mass of the corpora mammillaria not yet divided; *p*, pons Varolii. The cerebellum and medulla oblongata, *mo*, are seen behind and to the sides in both figures.

Tho lamina terminalis (lamina cinerea) continues to close the third ventricle in front, below it the optic commissure forms the floor of the ventricle, and further back the infundibulum descends to be united in the sella turcica with the tissue adjoining the posterior lobe of the pituitary body.

The two *optic thalami*, formed from the posterior and outer part of the anterior vesicle, consist at first of a single hollow sac of nervous matter, the cavity of which communicates on each side in front with that of the commencing cerebral hemispheres, and behind with that of the middle cephalic vesicle (corpora quadrigemina). Soon, however, by increased deposit taking place in their interior behind, below, and at the sides, the thalami become solid, and at the same time a cleft or fissure appears between them above, and penetrates down to the internal cavity, which continues open at the back part opposite the entrance of the Sylvian aqueduct. This cleft or fissure is the *third ventricle*. Behind, the two thalami continue united by the *posterior commissure*, which is distinguishable about the end of the third month, and also by the *peduncles of the pineal gland*. The *soft commissure* probably exists from an early period, although it could not be detected by Tiedemann until the ninth month.

Fig. 736.

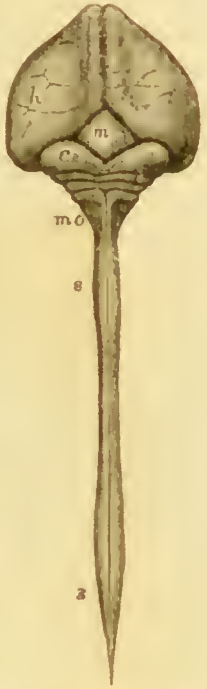


Fig. 736.—BRAIN AND SPINAL CORD OF A FŒTUS OF FOUR MONTHS, SEEN FROM BEHIND. (From Kölliker.)

h, hemispheres of the cerebrum; *m*, corpora quadrigemina or mesencephalon; *c*, cerebellum; *mo*, medulla oblongata, the fourth ventricle being overlapped by the cerebellum; *s s*, the spinal cord with its brachial and crural enlargements.

At an early period the *optic tracts* may be recognised as hollow prolongations from the outer part of the wall of the thalami while they are still vesicular. At the fourth month these tracts are distinctly formed. They subsequently are prolonged backwards into connection with the corpora quadrigemina.

The formation of the pineal gland and pituitary body presents some of the most interesting phenomena which are connected with the development of the thalamencephalon.

Pineal Gland. Epiphysis Cerebri.—As already stated, this body is formed by an out-folding from the back part of the inter-brain roof, at a place where the opposite sides remain united by nervous matter afterwards giving rise to the pineal peduncles. This body consists at first in all vertebrates of medullary substance covered by pia mater, and forms a median projection upwards, which in the lower tribes is also directed forwards in the form of a tube which reaches the roof of the cranium, and in some is united with or even passes through the cranial wall. It is in all deeply indented by vascular folds and growths of the pia mater. In mammals the original development of the pineal gland is the same as in the lower tribes; but it remains comparatively short, and its direction is backwards: and though it is at first permeated by epithelial tubes, or subdivisions of the ventricular cavity, it becomes at a later period solid by the deposit of various cellular and other materials. The gritty deposit was found in it by Sœmmerring at birth.

Pituitary body. Hypophysis Cerebri.—The general nature of this body in connection with an outgrowth of the brain on the one hand and a diverticulum of the alimentary canal on the other, and which was first pointed out by Rathke (1838, No. 195), has been already adverted to. The researches of W. Müller (No. 197), Goette (No. 200), and Mihalkovics (No. 198), have fully confirmed Rathke's view, and lead to the following general conclusions regarding it.

The infundibulum, as is well known, is a prolongation of the medullary wall of the third ventricle, originally in continuity with the epiblast; while the diverticulum from the alimentary canal is not, as was at one time supposed, from the pharynx, but from the mouth, and its lining is therefore continuous with the same layer of the blastoderm. This diverticulum is formed at an early period from the middle of the upper and back part of the buccal cavity before the faucial opening into the pharynx has taken place. The anterior attenuated extremity of the notochord is placed between the cerebral and buccal outgrowths, but it disappears as the lower one extends upwards and comes to unite with the infundibulum, and then the notochord is lost in the floor of the pituitary fossa with which both the outgrowths cohere (Mihalkovics).

Fig. 737.

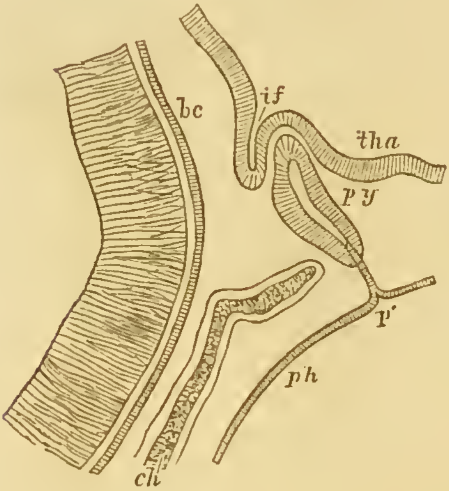


Fig. 737.—Vertical section of the infundibulum and pituitary diverticulum in the rabbit's embryo, after the opening of the fauces. (From Mihalkovics.)

For the earlier stages see fig. 705, p. 807, A and B. *bc*, dorsum sellæ; *if*, infundibulum; *tha*, floor of thalamencephalon; *py*, pituitary diverticulum, now closed; *p'*, stalk of original communication with the mouth; *ph*, pharynx; *ch*, notochord in the spheno-occipital part of the cranial basis.

The flask-like outgrowth of the buccal epiblast which gives rise to the hypophysis cerebri, is now gradually shut off from the corneous layer and cavity of the mouth by the constriction and subsequent closure of its communicating pedicle. There remains, however, for a considerable time, a longish thread of union between the two. The epithelium of the enclosed portion subsequently undergoes development into glandular cæca and cell-cords, and its internal cavity becomes gradually obliterated. This forms the anterior part or lobe of the pituitary body. The posterior part owes its origin in all vertebrates to the combination with mesoblastic tissue of a widened extension of the infundibular process of the brain, which is thrust in between the sac of the pituitary body and the dorsum sellæ. The nervous structure of this posterior lobe afterwards disappears in the higher animals, but in the lower the posterior lobe retains its place as a part of the brain.

The possibility of establishing a general homology between vertebrate and invertebrate animals, involves important considerations as to the relations of the forepart of the alimentary canal to the brain. In a recent memoir on this subject (No. 201), Professor Owen puts forward the view that the "conario-hypophysial tract," or passage through the pituitary diverticulum, infundibulum, third ventricle and pineal gland, may have been the means of carrying the anterior part of the alimentary canal from the ventral or hæmal to the dorsal or neural side of the head in an ancestral form of the vertebrate animal, and that thus (one of them being inverted) the several sets of organs in the two great divisions of the animal kingdom might be brought into corresponding relative position. According to the view taken by Dohrn (No. 199), the fourth ventricle is the place where the œsophagus may be supposed to have pierced the nervous ring.

5. Prosencephalon, Fore-brain.—Each *hemisphere-vesicle* may be considered to consist of two parts: one of these is the part which from the interior appears as the corpus striatum, and from the exterior as the island of Reil, or central lobe; the other forms the expanded or covering portion of the hemisphere, and is designated by Reichert the *mantle*. The lateral ventricles are placed internally between these parts. The aperture existing at the constricted neck of the ventricle where it expands into the hemispheres is the foramen of Monro.

The *corpora striata*, it will be observed, have a different origin from the optic thalami; for, while the latter are formed by thickening of the circumferential wall of a part of the first cerebral vesicle, and thus correspond in their origin with the parts of the encephalon behind them, the corpora striata appear as thickenings of the floor of the hemisphere-vesicles, which are lateral off-shoots from the original medullary tube. On this account, Reichert considers the brain primarily divisible into the stem, which comprises the whole encephalon forwards to the tænia semicircularis, and the hemisphere-vesicles, which include the corpora striata and hemispheres.

The cerebral hemispheres undergo enlargement at an early period in mammals, and especially in the human embryo, so that at the tenth week they have greatly surpassed in size all the other parts of the brain. They then form large hollow bodies with comparatively thin walls superiorly, the lateral ventricles being greatly

Fig. 738.

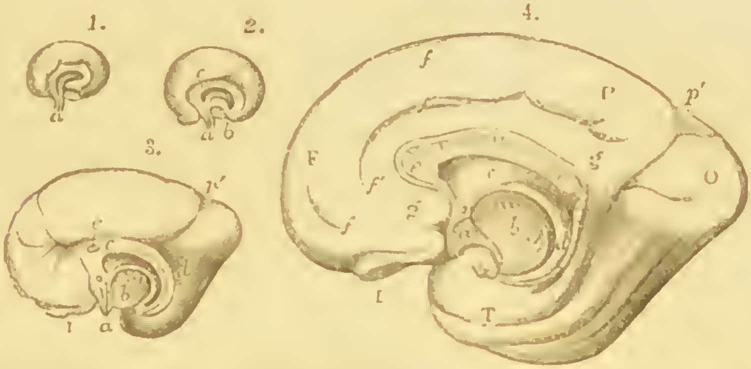


Fig. 738.—Semidiagrammatic views of the inner surface of the right cerebral hemisphere of the fœtal brain at various stages of development. (From Schmidt.)

1, 2, and 3, are from fœtuses of the respective ages of eight, ten, and sixteen weeks; 4, from a fœtus of six months. *a*, lamina terminalis or part of the first primary vesicle which adheres to the sella turcica; *b*, section of the cerebral peduncle as it passes into the thalamus and corpus striatum; the arched line which surrounds this bounds the great cerebral fissure; *c*, anterior part of the fornix and the septum lucidum; *d*, inner part of the arch of the cerebrum, afterwards the hippocampus major and posterior part of the fornix; *e*, corpus callosum very short in 3, elongated backwards in 4; in 4, *f*, the marginal convolution; *f′*, calloso-marginal fissure; *g*, gyrus fornicatus; *p′*, the parieto-occipital fissure descending to meet the calcarine fissure; I, olfactory bulb; F, P, O, T, frontal, parietal, occipital and temporal lobes.

Fig. 739.

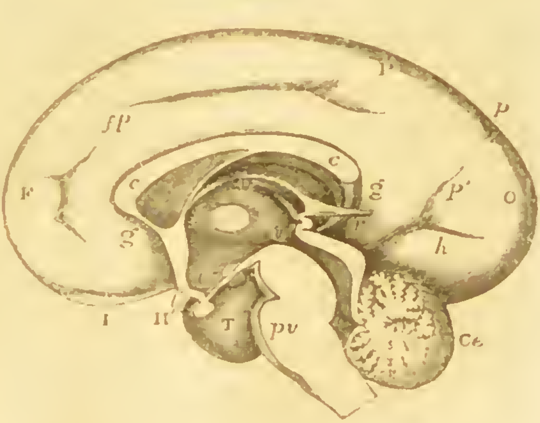


Fig. 739.—View of the inner surface of the right half of the fœtal brain of about six months. (From Reichert.)

F, frontal lobe; P, parietal; O, occipital; T, temporal; I, olfactory bulb; II, right optic nerve; *fp*, calloso-marginal fissure; *p*, external; *p′*, internal parts of the parieto-occipital fissure; *h*, calcarine fissure; *g*, gyrus fornicatus; *c*, *c*, corpus callosum; *s*, septum lucidum; *f*, placed between the middle commissure and the foramen of Monro; *v*, in the upper part of the third ventricle immediately below the velum interpositum and fornix; *v′*, in the back part of the third ventricle below the pineal gland, and pointing by a line to the aqueduct of Sylvius; *v″*, in the lower part of the third ventricle above the infundibulum; *r*, recessus pinealis passing backwards from the tela choroidea; *pv*, pons Varolii; *Ce*, cerebellum.

dilated, and communicating by a wide aperture with each other, and with the third ventricle, by the foramen of Monro. The growth of the hemispheres takes place progressively from before backwards, so that they come to cover in succession the thalami, corpora quadrigemina and cerebellum, which all originally stood in a series behind them, as they do permanently in the lowest vertebrates. By the end of the third month the hemispheres have extended so far backwards as to cover the thalami; at the fourth they reach the corpora quadrigemina; at the sixth they cover those bodies and great part of the cerebellum, beyond which they project still further backwards by the end of the seventh month.

The floor especially of the hemispheres thickens considerably, and the corpus striatum increasing greatly in magnitude, at the same time projects upwards into the lateral ventricles so as to give these cavities an arched form and mark out their anterior and descending cornua, while externally the distinction between the frontal and temporal lobes is indicated by the wide depression of the fossa of Sylvius. The floor of this part below the corpora striata becomes the island of Reil, or central lobe. The corpora striata and thalami, which are at first distinct, become more and more completely united together.

Fig. 740.

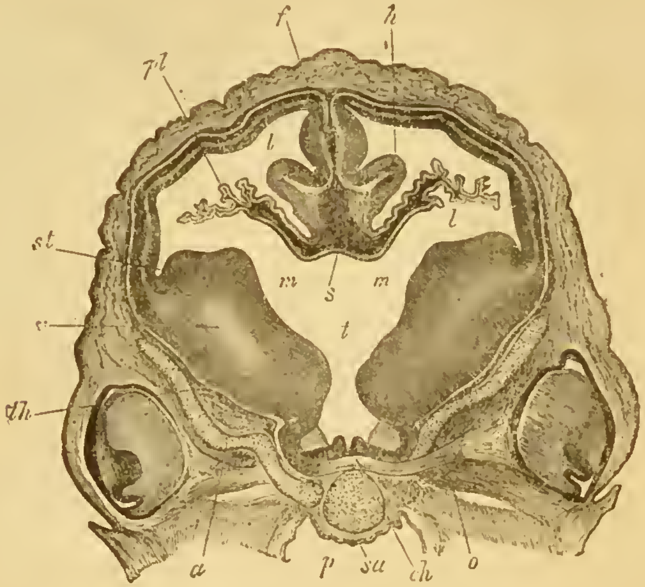


Fig. 740.—Transverse section through the brain of a sheep's embryo of 2·7 cm. in length. (From Balfour, after Kölliker.)

The section passes through the hemispheres and third ventricle. *st*, corpus striatum; *th*, optic thalamus; *t*, third ventricle; *c'*, their divergence into the walls of the hemispheres; *l*, lateral ventricle with choroid plexus *pl*; *h*, hippocampus major; *f*, primitive falx; *a*, orbito-sphenoid; *sa*, presphenoid; *p*, pharynx; *ch*, chiasma; *o*, optic nerve; *mm*, foramen of Monro; *s*, covering of lateral ventricles.

A deep notch separates the hemispheres above and posteriorly, but in front they are united together in the place of the original lamina terminalis, and here as farther back the inner walls becoming thinner are united together in a narrow partition which is the source of the septum lucidum and the commissures. The first of these to arise is the anterior commissure, which is also the lowest and unites the corpora striata. The fornix comes next in its anterior part, which with its pillars and the corpora albicantia is at first single and median; the posterior pillars follow, running back on each side into the cornu Ammonis of the descending cornua. The corpus callosum is last formed, consisting at first only of its fore part, as is permanently the case in monotremes and marsupials; but as the hemispheres extend themselves backwards, the corpus callosum elongates in the same direction, thus forming a roof for the subjacent lateral ventricles and other parts.

The fifth ventricle in the septum lucidum is not a part of the original common ventricular cavity of the brain, but is formed separately.

At the lower part of the inner walls two horizontal folds make their appearance below those of the fornix and hippocampi, which are covered by pia mater, and which, extending backwards from the foramen of Monro, cover in the third ventricle and occupy the great transverse fissure of the brain. These folds, extending themselves laterally and backwards, and becoming more and more plicated and vascular at the edges, give rise to the choroid plexus of the lateral ventricles and the velum interpositum.

The *olfactory lobes* are outgrowths from the lower and lateral parts of the cerebral hemispheres, being more immediately connected with the frontal lobes, but extending through the fissure of Sylvius as far as the temporal or middle lobes. They are at first hollow, and in some animals their cavity is in permanent communication with the lateral ventricles. In man they become solid at an early period.

Development of the Convolutions and Sulci.—Adopting the distinction of the convolutions and sulci of the cerebral hemispheres as of two kinds, viz., "primitive" and "secondary," according as the former result from a folding of the whole substance of the wall of the hemisphere, while the latter consist merely of depressions and elevations of its more superficial portion, it may be stated, with respect to their development, that the first of the primitive sulci to appear is the fissure of Sylvius, which is visible before the end of the third month (Ecker) as a wide shallow depression or fossa between the anterior and middle lobe of each hemisphere. Of the remaining primitive sulci, the hippocampal or dentate, the parieto-occipital and the calcarine, also begin to appear during the third month, and by the end of the fifth month are well established.

Fig. 741.

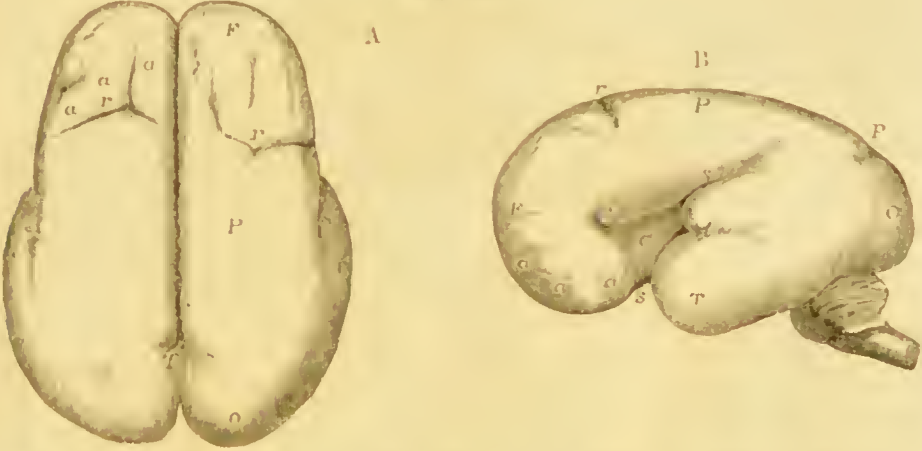


Fig. 741.—The Surface of the Fœtal Brain at Six Months. (From R. Wagner.)

This figure is intended to show the commencement of the formation of the principal fissures and convolutions. A, from above; B, from the left side. F, frontal lobe; P, parietal; O, occipital; T, temporal; *a*, *a*, *a*, slight appearance of the several frontal convolutions; *s*, the Sylvian fissure; *s'*, its anterior division; within it, C, the central lobe or convolutions of the island; *r*, fissure of Rolando; *p*, the parieto-occipital fissure.

The secondary sulci begin to appear about the fifth or sixth month: the first of these to be seen is the sulcus centralis, or fissure of Rolando. By the end of the sixth month the transverse frontal and inferior frontal furrows have appeared on the otherwise smooth surface of the frontal lobe, and at about the same time the first indications of the intraparietal fissure, with its continuation on the occipital lobe as the superior occipital furrow, the parallel, the calloso-marginal and collateral fissures become visible on the outer and inner aspects of the hemispheres. The lower surface now shows a slight trace of the inferior temporal furrow; and the fissure of Sylvius, which was at first a wide fossa, at this period begins to close in, especially at its hinder portion, an indication of its anterior division becoming now visible.

By the end of the seventh month nearly all the chief features of the cerebral convolutions and sulci have appeared. The superior frontal fissure can now be seen, and the three frontal convolutions are well marked. The fissure of Rolando has increased in length and depth. While the sulci that have already been spoken of are becoming better marked, the transverse occipital appears for the first time. Within the fissure of Sylvius, which has now a triangular form, two depressions are seen, the anterior bounding a prolongation of the olfactory tract, the posterior dividing the greater portion of the floor of the fissure into a fore and hind part. The island of Reil shows three convolutions divided by the forked sulcus insulæ primus. The sulci visible on the under surface of the hemispheres are still few and indistinct. Indications are found of a branched orbital sulcus, and of the olfactory sulcus, in which lie the olfactory bulb and tract. The middle temporal convolution, and the uncus and gyrus hippocampi, have now become fairly prominent.

During the eighth month a furrow appears behind the fissure of Rolando, parallel to it, and joining the intraparietal. This is the sulcus postcentralis of Ecker. The transverse occipital furrow now becomes very distinct, and joins the intraparietal farther back. The last fissures to appear are the inferior occipito-temporal and a small furrow crossing the end of the calloso-marginal. (Consult Nos. 28, 190, and 191.).

II. THE NERVES.

Fig. 742.

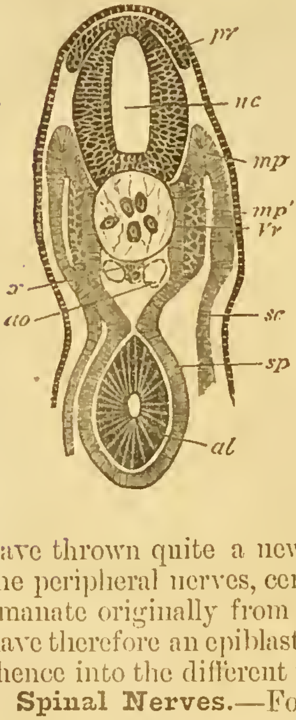


Fig. 742.—Transverse section through the trunk of an embryo shark, to show the neural crest. (From Balfour.)

nc, neural canal; *pr*, posterior root of spinal nerve: *x*, sub-notochordal rod; *ao*, aorta; *sc*, parietal mesoblast; *sp*, visceral mesoblast; *mp'*, muscle plate; *mp*, portion of muscle plate converted into muscle; *Vv*, portion of the vertebral plate which will give rise to the vertebral bodies; *al*, alimentary canal.

Very little was known till lately of the exact mode of origin of the peripheral nerves, and it was generally supposed that they were formed, as held by Remak, in more or less immediate connection with the parts of mesoblastic origin in which they were distributed. The only known fact inconsistent with this view was that the anterior or motor roots of the spinal nerves had been found to bud out from the ventral side of the spinal cord. The recent researches especially of His, Balfour, and Marshall, Kölliker, Hensen and others, have thrown quite a new light on this subject, and have shown that all the peripheral nerves, cerebro-spinal and sympathetic, with their ganglia, emanate originally from the primary brain and spinal marrow, that they have therefore an epiblastic origin, and that they spread more or less from thence into the different parts of the body. (See Nos. 28 and 202—205.)

Spinal Nerves.—Following the description of their origin given by Balfour and Marshall, it may be stated that the posterior roots of the spinal nerves and most of the cranial nerves, with their respective ganglia, which are formed before the anterior roots, proceed from a series of cellular swellings, constituting the *neural crest*, which are in continuity with the medullary plates close to the place of inflection of the epiblast into the involution which forms the primary brain and spinal cord. These root swellings are in some animals connected together by a longitudinal band or commissure. In the primitive projections there are soon distinguished a narrower first part or root, then a thicker part, the ganglion, and further down a part of the nerve extending beyond it. The root originally connected with the upper part of the medullary wall close to the median line slips down, as it were, upon the side, and is subsequently united laterally with the medullary wall at a lower place, leaving the upper end of the root for a time apparently free. This process begins in the chick at the end of the second day, and in the embryo of the rabbit on the ninth day.

Fig. 743.

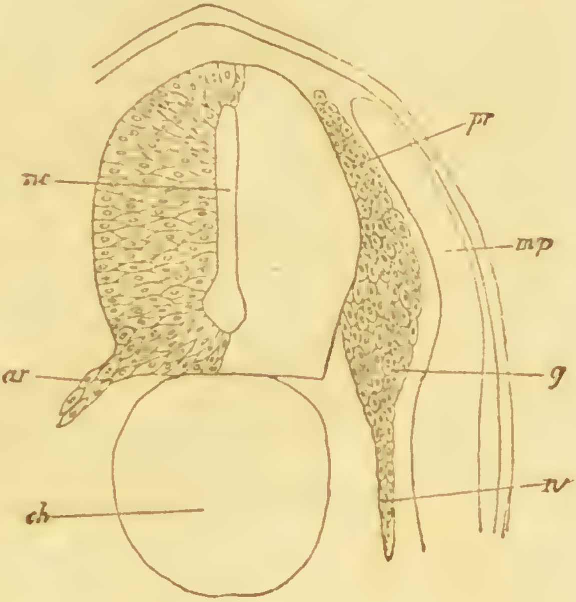


Fig. 743.—Section through the dorsal part of the trunk of a torpedo embryo. (From Balfour.)

pr, posterior root of spinal nerve; *g*, spinal ganglion; *n*, nerve; *ar*, anterior root; *ch*, notochord; *nc*, neural canal; *mp*, muscle-plate.

The anterior roots of the spinal nerves are also outgrowths from the medullary wall. They begin to appear somewhat later than the posterior roots, as projections from its ventral side, and extending from thence outwards, come to join the nerve which emanates from the ganglion of the posterior root; and from this point the compound nerve grows towards the periphery or region of its distribution. The place at which the anterior roots spring from the spinal cord is not opposite to the corresponding posterior root, but midway between that root and the succeeding one. Both roots and ganglion have at first a cellular structure, and their fibres are of later origin, the cells being largest in the ganglion, and the fibres appearing earlier in the anterior than in the posterior roots.

Cranial Nerves.—Most of the cranial nerves, viz., the olfactory, the 3rd, 5th, and 7th, the auditory, the glossopharyngeal, and the vagus, arise from a neural crest in a manner analogous to the spinal posterior roots; and in the chick the ridge from which some of them spring is perceptible even before the closure of the medullary canal at its dorsal lip of inflection (Marshall); and as it is more immediately attached to the medullary than to the epidermal part of the epiblast, the cranial nerve-roots may be regarded as taking their origin from the rudimentary brain.

The cerebral neural crest is continuous with that of the spinal marrow. It extends to the roof of the mid-brain, and there is the same shifting downwards of the attachment of the roots to the neural crest as in the spinal nerves. In most of the nerves it has been observed that a subdivision occurs into portions representing a root, a ganglion, and a peripheral nerve-trunk. The change of the place of attachment is most remarkable in the case of the third nerve, which is carried down quite to the lower surface of the mid-brain.

The sixth and the twelfth (or hypoglossal) nerves may arise, according to Marshall, as motor or lower roots of certain of the other nerves; but the mode of origin of these two nerves, as well as of the fourth, has not yet been fully ascertained, and Balfour doubts whether the cranial nerves before described as arising dorsally from a neural ridge or crest, are, like the dorsal roots of the spinal nerves, exclusively sensory. Some of them, he holds, are undoubtedly mixed, and all of them may be so. (No. 205.)

Fig. 744.

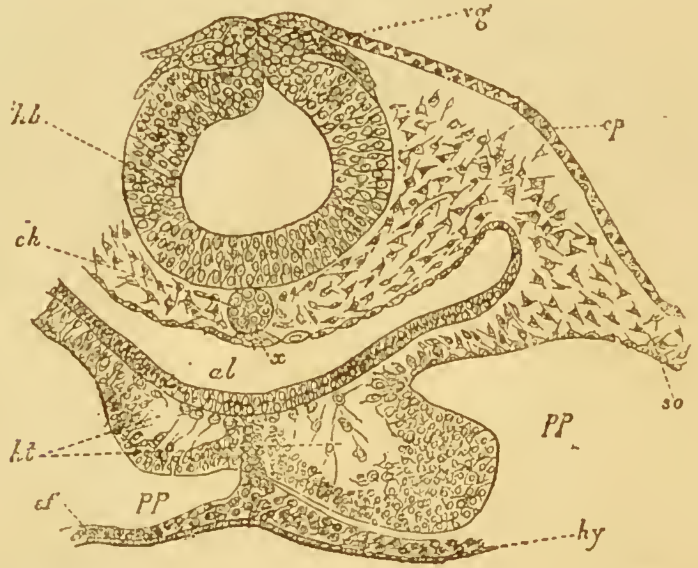


Fig. 744.—Transverse section through the posterior part of the head of an embryo chick of 30 hours. (From Balfour.)

hb, hind-brain; *vg*, vagus nerve; *ep*, epiblast; *ch*, notochord; *x*, sub-notochordal rod; *al*, throat; *ht*, heart; *pp*, body-cavity; *so*, parietal mesoblast; *sf*, visceral mesoblast; *hy*, hypoblast.

The olfactory nerve is certainly an outgrowth from the fore-brain; but whether from an extension forwards of the neural crest or not is still doubtful. In the olfactory nerve of mammalian embryoes, A. Fraser has observed the root ganglion and two main divisions of the nerve forking over the nasal pit (see fig. 745).

The origin of the Optic nerve and retina from the primitive medullary fore-brain (as will be shown later) is different from that of all other nerves.

The fifth nerve, shortly after its origin in connection with a neural crest like the rest, undergoes the shifting change of position, and is united to the rudiment of the large Gasserian ganglion. Of its three principal branches the inferior maxillary belongs to the mandibular arch, in the hinder part of which it is placed. Its ophthalmic and superior maxillary divisions are premandibular, and according to Balfour probably belong to face-arches in that situation. The superior and inferior maxillary divisions fork over the cleft of the mouth, while the ophthalmic branch is connected with the third nerve in the ciliary ganglion.

The facial and auditory nerves appear to have a common origin. The main destination of the facial, as seen at an early period, is the hyoid arch, but it also sends forward a branch which is very large in young embryoes, forks over the hyo-mandibular cleft, and joins the inferior maxillary of the fifth in the mandibular arch as the chorda tympani of mammals. Besides this, two other branches

Fig. 745.

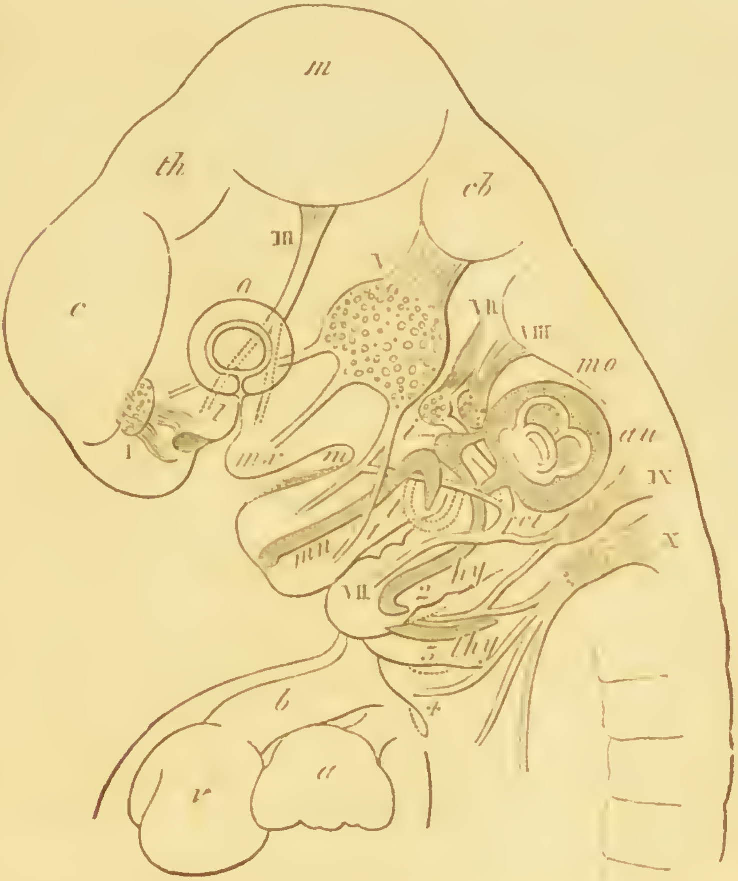


Fig. 745.—OUTLINE DIAGRAM OF THE HEAD OF A MAMMALIAN EMBRYO, CORRESPONDING TO A HUMAN EMBRYO OF EIGHT WEEKS, SHOWING THE RELATION OF SOME OF THE PRINCIPAL CRANIAL NERVES TO THE VISCERAL ARCHES AND THE DEVELOPMENT OF THE OSSICULA AUDITUS. (After A. Fraser, A.T.)

c, Cerebral hemispheres; *th*, thalamencephalon; *m*, midbrain; *cb*, cerebellum; *mo*, medulla oblongata; *o*, eye; *I*, olfactory ganglion and nerves passing to nasal cleft; *III*, third nerve; *V*, fifth nerve with Gasserian ganglion and its three branches; *VII*, facial nerve; *ct*, its chorda tympani branch; *VIII*, the auditory nerve; *IX*, glossopharyngeal nerve forking over the second postoral cleft; *X*, vagus; *l*, lachrymal cleft; *mx*, maxillary arch; *m*, mouth with indication of tongue; *mn*, mandibular cartilage with malleus forming in its proximal part; *i*, incus forming in the second cartilaginous arch; *t*, indication of the lower part of tympanic ring; *au*, the auditory capsule, semicircular canals, &c.; *hy*, hyoidean cartilage; *thy*, thyro-hyoidean cartilage; 1, 2, 3 and 4, indicate the places of the postoral clefts which are now closed; *b*, aortic bulb; *r*, ventricles of the heart; *a*, left auricle.

proceed forward from the facial, which are proportionally large in the embryo, viz., the superficial ophthalmic and the palatine (or superficial petrosal), which are respectively associated with the ophthalmic and superior maxillary divisions of the fifth nerve.

The auditory nerve, which proceeds at once to join the labyrinth of the ear, has a ganglion developed upon it at a very early period.

The glosso-pharyngeal nerve is connected with the third visceral or first true branchial arch, and in the lower vertebrates the pneumo-gastric or vagus is distributed to this and the branchial arches which follow in whatever number they may be. These nerves have in the chick a common origin from the dorsal neural crest of the after-brain, but, like the other nerves previously mentioned, they afterwards shift downwards so as to be placed on the sides.

According to Balfour some of the cranial nerves, such as the third, fifth and facial, besides the glossopharyngeal and vagus, may be held to bear definite relations to mesoblastic somites or muscle plates of the head, each being placed immediately behind the head-cavity of its respective somite. As stated by Parker, this relation is the following. Each of these nerves divides or forks above a visceral cleft, one division going to the posterior face of the arch in front of the cleft, the other to the anterior face of the arch behind it.

Fig. 746.

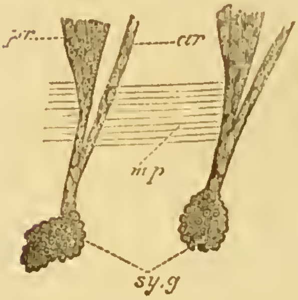


Fig. 746.—Longitudinal vertical section through part of the body-wall of an elasmobranch embryo showing two spinal nerves and the sympathetic ganglia belonging to them. (From Balfour.)

ar, anterior root; *pr*, posterior root; *sy.g*, sympathetic ganglion; *mp*, part of muscular plate.

The orbito-nasal and the palatine divisions of the trigeminus belong to an anterior arch, the former above, the latter below the optic nerve. The superior maxillary division follows the palato-pterygoid arch, the inferior maxillary nerve accompanies the mandibular arch.

The facial nerve divides above the hyo-mandibular cleft, its anterior part (chorda tympani) going to the posterior side of the mandibular arch, and its posterior part to the outer or anterior side of the hyoid arch.

The glosso-pharyngeal nerve, by a similar division, goes by its anterior branch to the posterior side of the hyoid arch, and by its other division to the front of the first branchial or thyro-hyoid arch.

In the higher animals the pneumo-gastric nerve shows no close relation to the clefts, but in branchiate vertebrates it forks over the remaining gill clefts and supplies branches to the gill arches.

Sympathetic Nerves.—It has been ascertained by Balfour that the sympathetic ganglia and nerves arise in connection with the gangliated roots of the cranial and spinal nerves, and they may therefore be regarded as springing from the same neuro-epiblastic source. This fact has been confirmed for birds and mammals by Schenk and Birdsell (No. 207).

The gangliated cord of the sympathetic has been described and figured by Kölliker in the human fœtus of eight or ten lines long. The peripheral sympathetic nerves are also formed at a very early period, and are perceptible in a fœtus of three months.

The Suprarenal Bodies.—The belief of a relation subsisting between the suprarenal bodies and the sympathetic ganglia of the nervous system seems to have originated with Bergmann in 1839, and to have received confirmation on embryological grounds from Remak in 1847, who called these bodies "nerve glands." It has, in fact, been long known that they have not any connection either by their origin or their permanent structural relations with the Wolffian bodies or with the kidneys. Leydig showed (1853) that in the adult plagiostomes, ganoids and reptiles the organs which represent the suprarenal bodies of the higher animals consist of two separate sets of parts, of which one is intimately associated with the sympathetic ganglia and contains ganglionic cells, while the other is of a different nature. Kölliker's observations in the human embryo (No. 28, i. p. 618) gave further support to the view of the nervous nature and origin of these bodies; and more recently the researches of Balfour in elasmobranchs, Braun in reptiles and Brunn in birds, have led the first of these authors to state confidently the general view that while in elasmobranchs and some others of the lower vertebrates (No. 32, Vol. II. pp. 548–9) the suprarenal bodies consist of two distinct parts, viz., one median and single which he proposes to call "interrenal" of mesoblastic origin, and the other paired and derived from the sympathetic ganglia, in the amniota these two sets of parts are combined in the paired organs which constitute the compound suprarenal bodies. The development of these two sets of parts is, however, distinct; that derived from the mesoblast being converted into the cortical part, and the substance which proceeds from the ganglia being enclosed within the first in the course of their development.

The development of the suprarenal bodies of mammalia has very recently been made the subject of investigation by Mitsukuri (No. 212) in the rabbit and rat, the result of which fully confirms Balfour's views, and shows that in these animals the medullary part of the suprarenal bodies arises by development from the sympathetic ganglia of the abdomen lying below the aorta, that the cortical substance is of a totally different nature and of mesoblastic origin, and that the two sets of parts are gradually combined in the course of their formation. The medullary or nervous substance is at first situated outside the cortical or mesoblastic element, but gradually insinuates itself into the interior, retaining, however, some connection with the neighbouring ganglia. In the lower vertebrates, as already stated, this combination has not taken place, the two components of the suprarenal bodies remaining distinct and separate.

III. PRINCIPAL ORGANS OF SENSE:

1. THE EYE.

Primary Development.—The embryonic structures forming the eyeball and its contents may be considered as proceeding from three sources, viz., 1st, by evolution or expansion from the medullary wall of the thalamencephalon, giving rise to the retina in its nervous and pigmental structure and to the optic nerve; 2nd, by involution and development of a part of the cuticular epiblast, forming the foundation of the lens and the epithelium of the conjunctiva; and 3rd, by the intrusion of mesoblastic elements between and around the other parts, so as to furnish the materials out of which are formed the external coverings of the eyeball, cornea and sclerotic, the fibrous and vascular choroid, the ciliary apparatus and iris, the capsule of the lens and the capsulo-pupillary membrane, the vitreous humour, and all the fibrous and vascular parts of the organ.

The very early formation of the *primary optic vesicles* has been already mentioned, p. 823. The bulging wall of the anterior primary vesicle which is thus projected outwards on each side gives rise, by the subsequent folding and changes which occur in it, to the nervous part of the eye, viz., the retina and optic nerve, together with the pigmental layer which comes to lie external to the retina. This folding takes place simultaneously with the development of the crystalline lens, which is the product of an involution of the cuticle or epiblast occurring on the outside of each primary optic vesicle. During the involution and enlargement of the lens, the wall of the primary optic vesicle comes to be depressed and doubled in upon itself, so as to form a cup-like hollow towards the exterior, the secondary optic vesicle, into which the lens is received, but without filling entirely its cavity. The outer plate or involuted portion of this cup or secondary optic vesicle becomes by its further development and histological differentiation the nervous part of the retina, while the remaining inner or proximal plate is converted into its pigmental layer, and the stalk becomes the optic nerve in connection with the brain.

Fig. 747.

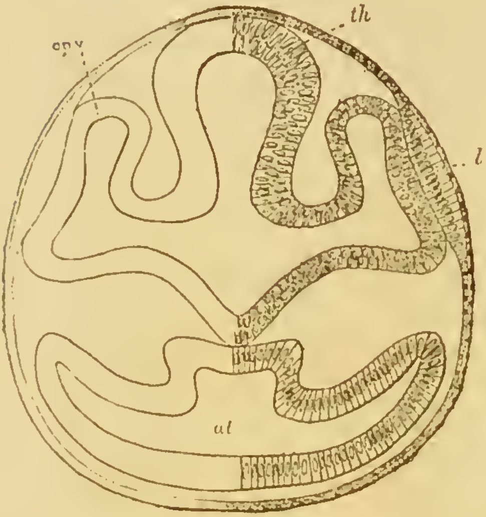


Fig. 748.

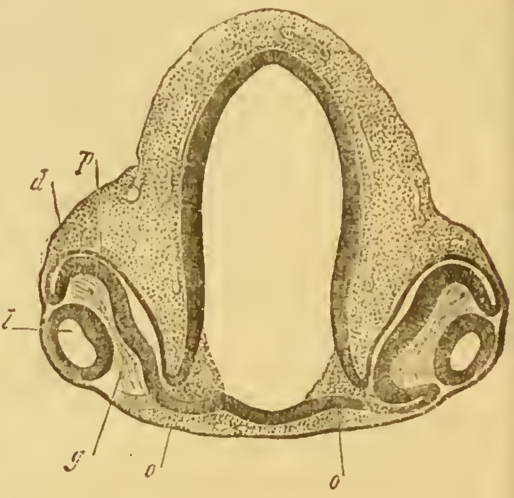


Fig. 747.—Section through the front part of the head of a Lepidosteus embryo. (From Balfour.)

al, alimentary tract; *th*, thalamencephalon; *l*, lens of the eye; *op.v*, the optic vesicle.

Fig. 748.—Frontal section through the head of an embryo chick of 3 days and 6 hours. (From Kölliker.) $\frac{40}{1}$

o, stalk of the ocular vesicle in connection with the thalamencephalon; *p*, proximal and *d*, distal wall of secondary ocular vesicle; *l*, lens; *g*, vitreous body.

The transition at the line of inflection from the thick nervous part to the thin pigmental part is quite sudden, and as soon as pigment cells begin to be developed a very marked distinction is perceptible between the latter and the nervous structure of the retina. These cells were formerly regarded as a part of the choroid membrane, but they are now looked upon as belonging rather to the retina,—a view which is fully warranted by the mode of development now described.

Fig. 749.

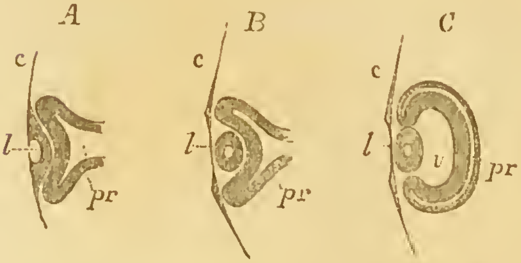


Fig. 749.—Section of the commencing eye of an embryo in three stages. (From Remak.)

A, commencement of the formation of the lens *l*, by depression of a part of C, the corneous layer; *pr*, the primitive ocular vesicle now doubled back on itself by the depression of the commencing lens.

B, the lens depression enclosed and the lens beginning to be formed in the inner side, the optic vesicle more folded back.

C, a third stage, in which the secondary optic vesicle, *v*, begins to be formed.

The fold which produces the optic cup proceeds from above downwards, and surrounds the lens so as to appear to enclose it, but leaves for a time an aperture or depression below. This is the *choroidal fold* or fissure, which may easily be distinguished in the embryo-head after pigment has been deposited, from the circumstance that the pigment is absent from the cleft, which thus appears for a time as a broad white line, particularly obvious in the embryo bird, running from the circumference in upon the lens.

Fig. 750.

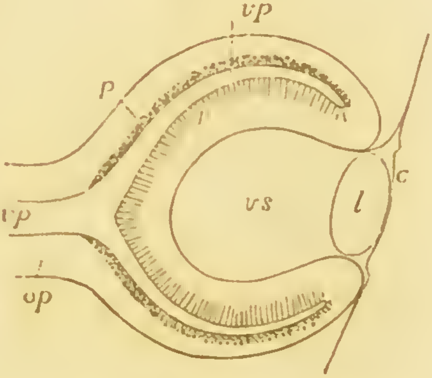


Fig. 750.—DIAGRAMMATIC SKETCH OF A VERTICAL LONGITUDINAL SECTION THROUGH THE EYEBALL OF A HUMAN FŒTUS OF FOUR WEEKS. (After Kölliker.) $\frac{100}{1}$.

The section is a little to the side so as to avoid passing through the ocular cleft. *c*, the cuticle, where it later covers the cornea; *l*, the lens; *op*, optic nerve formed by the pedicle of the primary optic vesicle; *vp*, primary medullary cavity of the optic vesicle; *p*, the pigment-layer of the outer-wall; *r*, the inner wall forming the retina; *vs*, secondary optic vesicle containing the rudiment of the vitreous humour.

The lens is developed in the part of the cuticle opposite to the most projecting part of the primary optic vesicle, or at the place where this vesicle comes in contact with the surface of the head. In this situation there is seen from a very early period a thickening of the epiblast, which seems to reside chiefly in its deeper layer of cells, and in birds and mammals it would appear that an actual involution of the cuticle takes place, so that first an open follicle and next an enclosed ball of cuticle is formed. Although, however, both the corneous and the deeper layer (sensory of Stricker) of the cuticle are enclosed, it is only the cells of the deeper layer which undergo development into the fibres of the lens. The external cuticle separating from the ball of the lens, passes freely over its surface, and a cavity filled with loose cells exists for a time within the lens. Then the cells of the hinder or inner wall are seen to rise from the bottom by their elongation, and thus a rapid growth of fibres from that side of the lens takes place, while the anterior or outer wall undergoes no similar change, but retains its simply cellular structure. Figures 751 and 752 show sufficiently clearly the manner in which the fibres thus

Fig. 751.

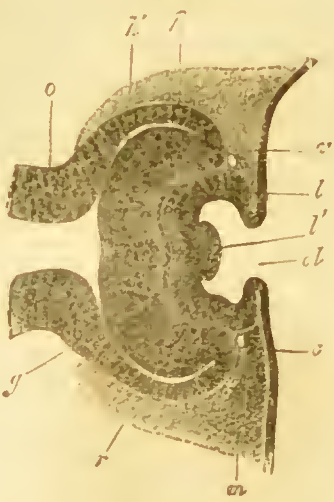


Fig. 751.—HORIZONTAL SECTION THROUGH THE EYE OF AN EMBRYO RABBIT OF TWELVE DAYS AND SIX HOURS. $\frac{10}{1}$. (From Kölliker.)

o, stalk of the ocular vesicle with wide cavity; *h'*, remains of the cavity of the primitive ocular vesicle; *p*, proximal lamella of the secondary vesicle (pigmentum nigrum); *r*, distal lamella (retina); *g*, vitreous body; *l*, lens vesicle, widely open at *ol*; *l'*, papillar elevation in the bottom of the lens vesicle which forms the lens; *m*, with *v*, an annular vessel at the anterior border of the secondary vesicle; *e*, epiblast.

developed from cells rise from the bottom of the lens ball and come to constitute its solid part.

The optic cup receives the enlarging lens in its anterior and lower opening, and the reflected margins of the cup closely embrace the margin of the lens; but there soon comes to be a considerable space intervening between the lens and the hollow of the optic cup (or secondary vesicle), which is later occupied by the vitreous humour. Into this space connective tissue and blood-vessels developed from mesoblastic elements are projected from below, so as to furnish the materials for the formation of the vitreous humour and the blood-vessels which pass through it to the lens, and also to surround the lens with vascular and fibrous elements, out of which are produced the *capsulo-pupillary membrane*, and probably also the capsule of the lens. It results from the observations of Lieberkühn (No. 216) that in mammals the fold which produces the ocular cup or secondary vesicle runs back into the stalk so as to fold in the optic nerve for a considerable space, and by the simultaneous enclosure of mesoblastic tissue thus to lead to the introduction of the central blood-vessels of the retina within the nerve. But in birds, according to the same observer, no such infolding of the stalk occurs, so that in them the vessels are excluded from the nerve. The malformation termed *coloboma*

Fig. 752.

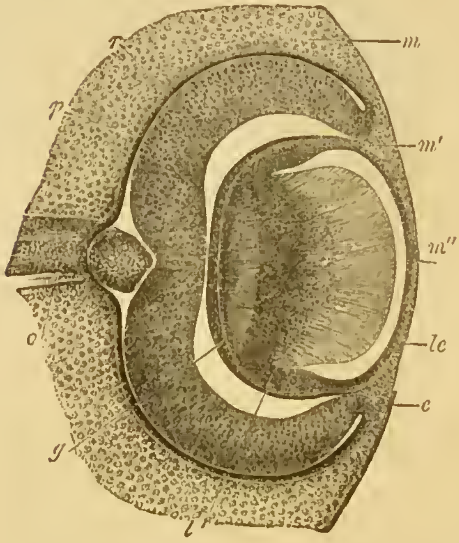


Fig. 752.—Eye of an embryo rabbit of 14 days; horizontal section. $\frac{65}{1}$. (From Kölliker.)

o, optic nerve; *p*, pigmentum nigrum; *r*, retina; *g*, vitreous body, which by its contraction has left a space behind it; *l*, posterior thick wall of the lens-vesicle, or rudiment of the lens; *lc*, anterior thin wall or lens epithelium, and between them the hollow of the lens vesicle; *m*, mesoderm surrounding the secondary ocular vesicle, no sclerotic or choroid yet formed; *m'*, connection of this with the vitreous body; *m''*, thin layer of mesoderm in front of the lens or rudiment of the cornea and pupillary membrane; *c*, portion of the epithelium of the front of the eye.

Fig. 753.

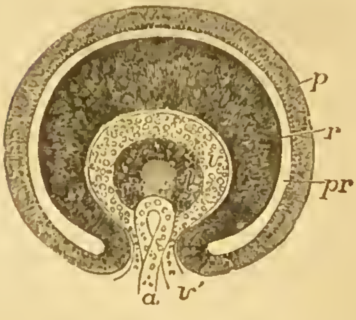


Fig. 753.—Transverse vertical section of the eyeball of a human embryo of four weeks. (From Kölliker). $\frac{100}{1}$.

The anterior half of the section is represented. *pr*, the remains of the cavity of the primary optic vesicle; *p*, the inflected part of the outer layer, forming the retinal pigment; *r*, the thickened inner part giving rise to the columnar and other structures of the retina; *v*, the commencing vitreous humour within the secondary optic vesicle; *v'*, the ocular cleft through which the loop of the central blood-vessel, *a*, projects from below; *l*, the lens with a central cavity.

iridis is to be attributed to a persistence of the choroidal cleft, and the pecten of birds, close to the optic nerve, with the vascular fold farther forwards, and the falciform fold of the eyes of fishes are to be regarded as fibro-vascular structures formed by original projection through the same interval.

The **further development** of the parts of the eye may be briefly stated as follows:—

The expansion of the ocular cup continuing to proceed, the chamber for the vitreous humour enlarges, and that structure gradually comes to occupy the space between the retina and the lens.

Fig. 754.

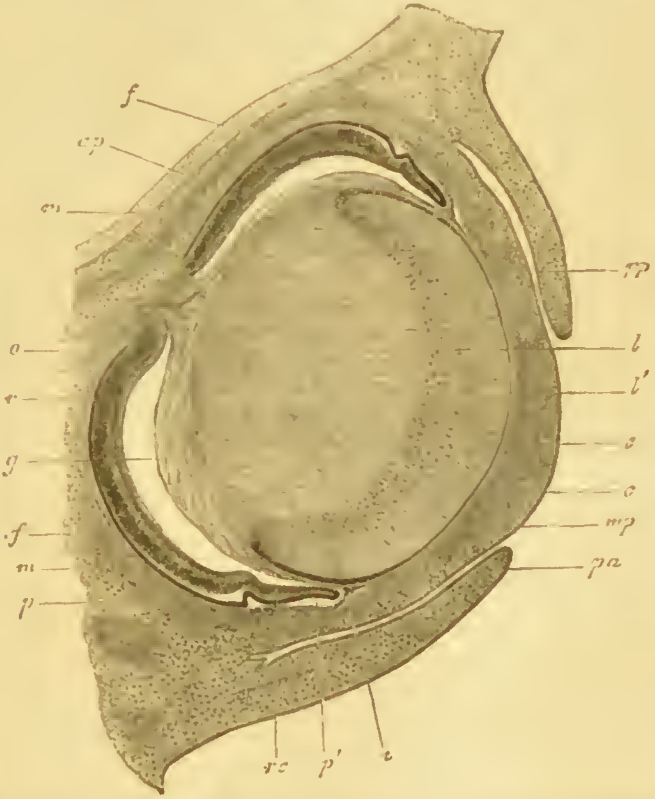


Fig. 754.—Horizontal section through the eye of an embryo rabbit of 18 days. $\frac{40}{1}$. (From Kölliker.)

o, optic nerve ; *ap*, ala parva ; *p*, pigmentum nigrum ; *r*, retina: *rc*, ciliary part of the retina ; *p'*, forepart of the secondary ocular vesicle or rudiment of the iris pigment ; *g*, vitreous body raised from the retina by shrinking, except where the vessels from the centralis retinæ enter it ; *i*, iris ; *mp*, membrana pupillaris: *c*, cornea with epithelium *e* ; *pp*, *pa*, palpebræ ; *l*, lens ; *l'*, lens epithelium ; *f*, sclerotic ; *m*, recti muscles.

The marked distinction between the nervous and the pigmental portions of the primitive ocular vesicle goes on increasing by the continued deposit of pigment in the latter, and its proportional thinning, and by the great addition to the thickness and the textural differentiation of the substance of the former. Thus the cells in the retinal or nervous portion, by their rapid multiplication, soon become several layers thick; certain of these cells assume the spindle shape, and exhibit elongation into fibres, while others retain the nuclear form, and thus there is foreshadowed the division into the fibrous, ganglionic, and nuclear layers of the retina. On the exterior a limiting membrane makes its appearance, and in connection with it the rudiments of the cells composing the layer of rods and cones. The space between the retinal and pigmental layers rapidly contracts, and finally the rods and cones are closely united with the layer of pigment cells.

The optic nerve, as already described, is at first connected by its origin with the vesicle of the third ventricle or thalamencephalon, and for a time it retains its earlier hollow form. But as the cerebral hemispheres are developed forwards, the eye and the optic nerve are thrown backwards and downwards, and a new connection is established between the optic nerve (or tract) and the vesicle of the mid-brain (mesencephalon): the rudiment of the optic commissure is at the same time formed by the median approximation of the stalks and the growth of one over the other. Each stalk then becomes more and more solid by the development of nerve fibres and the formation of the sheath substance of the nerve from the enclosed connective tissue.

Retina and Optic Nerve.—The full development of the minute nervous structures of the eye is a subject of great difficulty, and observers are not quite agreed as to its phenomena. The rods and cones are undoubtedly formed in connection with the cells of the outer granular layer, but their outer and inner limbs are probably formed from different cells, the membrana limitans externa being at an early period placed between. According to Kölliker the layer of ganglion cells and the inner molecular layer are the first to be differentiated, and are very soon followed by the nerve fibres which spread over the interior of the retina. A somewhat different account of the process is given by Löwe (No. 222*), to whose work we must refer the reader.

At the ora serrata the denser nervous structure of the retina ceases, and in front of this, as far as the inflection of the distal into the proximal or pigmental layer, the retina is continued as the thinner ciliary portion, bounded externally by the pigment of the ciliary processes.

It has generally been held, and it is still the opinion of some, that the pedicle of the optic vesicle is converted into the optic nerve by the differentiation of its substance into nerve fibres. But a different view has been taken by His and by Kölliker (No. 28, i. p. 690) according to which the original substance of the pedicle is supposed to furnish only the supporting structures, and the nerve fibres are formed by secondary emanation from the chiasma or nervous centre.

According to Kölliker the yellow spot is not yet visible at birth.

Lens.—The development of fibres from the hinder wall of the primitive lens-follicle continuing to take place, the cavity of the follicle is first greatly narrowed and then completely filled up by the lengthening fibres, and the lens takes more and more of its full spherical shape. The new fibres continue to be formed towards the margin of the lens; each fibre retaining its nucleus, so as to produce the *nuclear zone* which runs through the whole lens. This zone is at first situated far back in the lens while the fibres are still short, but as they elongate its place is advanced, so that it comes to be situated considerably in front of the equatorial plane of the lens. It is most distinct towards the margin where the fibres are newly formed. The anterior wall of the lens-follicle remains as a simple cellular layer. The greater number of the fibres now follow the general curve of the surface of the lens, presenting therefore their concavity towards its centre, but the curvature gradually diminishes in those nearest the middle, where they are straight, or nearly so. Only the external short and recently formed fibres present a concavity towards the exterior. The intersecting stars of the anterior and posterior poles of the lens now make their appearance by the collection of cells in the peculiarly shaped triradiate or multiradiate space in these two situations, and the ends of the fibres are now traceable to the edges of these spaces, so that the fibres gradually take the arrangement round the poles of the lens which belongs to the adult.

The origin of the capsule of the lens appears to be still somewhat doubtful. Lieberkühn, Arnold and Löwe profess to trace it to a thin pellicle of mesoblast which at an early period passes in between the lens and the secondary ocular vesicle; but Kölliker and Kessler are of opinion that it is a cuticular deposit on the surface of the lens cells. Balfour is inclined to adopt the latter view, on the ground that the capsule seems to make its appearance before the introduction of the mesoblast has occurred.

The *fibro-vascular structures* of the eye, which are all derived from mesoblastic elements, either surrounding the secondary ocular vesicle or passing into it by the choroidal fissure, may be considered as consisting of three sets of parts, viz., 1st, that which is external to the ocular cup and which becomes the sclerotic, the cellular substance of the cornea and also the choroid membrane; 2nd, that which occupies the interior of the optic cup, and which becomes the vitreous humour, and the capsulo-pupillary membrane with the arteria centralis retinæ; and 3rd, that which is developed in the angle of meeting of the two parts previously mentioned, *i.e.*, between the margin of the lens and the reflection of the two layers of the optic cup, and in which the ciliary processes, ciliary muscle and iris are mainly formed. The pigmental elements which any of these parts possess are derived from that of the retina or proximal wall of the optic cup.

Cornea.—The formation of the cornea is mainly due to a differentiation of the tissue in the layer of mesoblast which is interposed between the primitive lens-follicle and the corneous epiblast. The layer forming the cornea is at first very thin, and quite homogeneous, and it has been doubted if this is mesoblastic; soon, however, the corneal cells, proceeding from mesoblast which advances from the margin, penetrate the homogeneous layer, and gradually progress towards the centre, greatly thickening it, and dividing it into layers. The original homogeneous substance which is left free of cells at its margins constitutes the outer and inner elastic layers. Within these is the cellular layer of the membrane of Descemet, which comes from a different source. There is at first no aqueous chamber in the eye, and even after the solution of continuity which gives rise to this space has occurred, the cavity is not dilated with fluid, till near the time of birth. Even then it is very shallow and the lens is placed close to the cornea, in the greater part of its surface. The cavity of the aqueous humour arises by the separation of the cornea from a layer of the mesoblastic tissue lying within it. The latter gives rise to the anterior part of the vascular capsulo-pupillary membrane.

Sclerotic Coat.—The outer covering of the eyeball is formed from mesoblastic cells surrounding the ocular cup, and is probably continuous with the structure which furnishes the corneal cells, but it is only later that the cornea and sclerotic come to be completely amalgamated.

Choroid membrane.—The mesoblastic substance which surrounds the ocular vesicle externally is the source of important parts. Among these may be mentioned first the choroid membrane, the cellular (membrana fusca), fibrous, and vascular layers of which are developed out of the deeper division of the mesoblastic substance, and to the same source may be traced the ciliary processes, ciliary muscle and iris; while the zonula ciliaris may be regarded as a part of the deeper mesoblastic tissue connected with the formation of the hyaloid membrane and membrana capsulo-pupillaris.

The **capsulo-pupillary membrane**, already referred to, may be looked upon as at first a complete fibro-vascular investment of the lens, which owes its origin to the deepest part of the enclosed mesoblast. The vessels of this membrane are supplied by a branch of the central artery of the retina, which passes forwards in the axis of the globe, and breaks up at the back of the lens into a brush of rapidly subdividing twigs. The forepart of this tunic, adherent to the pupillary margin of the iris, forms the *pupillary membrane* by which the aperture of the pupil is closed in the middle periods of fœtal life. In the human eye, the whole tunic, together with the artery which supplies its vessels, becomes atrophied and is lost sight of before birth, but in some animals it remains apparent for a few days after birth. According to Kölliker, the anterior chamber expands only a short time before birth by the intervention of the aqueous humour between the iris and cornea.

Fig. 755.

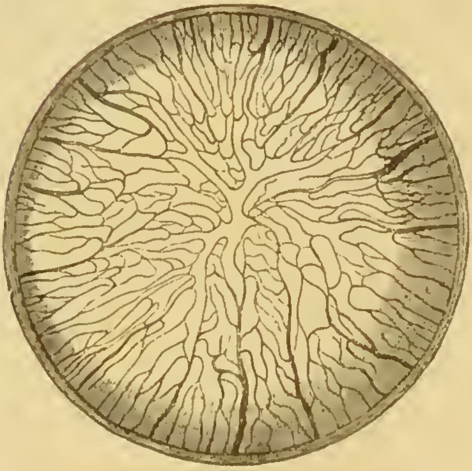


Fig. 755.—Blood-vessels of the capsulo-pupillary membrane of a new-born kitten, magnified. (From Kölliker.)

The drawing is taken from a preparation injected by Tiersch, and shows in the central part the convergence of the network of vessels towards the centre of the pupillary membrane.

The iris is developed from a proliferation of mesoblastic tissue which takes place in the angle between the anterior reflection of the walls of the ocular cup and the margin of the lens and cornea, and it is intimately connected with the capsulo-pupillary membrane, with which, indeed, it appears to be continuous anteriorly. It is thus in relation with all the fibro-vascular structures of the eye. It derives its pigmental layer from a reduplication of the anterior part of the pigmental layer of the ocular cup. It does not acquire free surfaces till after the formation of the aqueous chamber.

The ciliary muscle is developed in the mesoblastic tissue between the base of the iris and the ciliary processes of the choroid membrane.

Vitreous Humour and Hyaloid Membrane.—These parts are usually regarded as being derived from the intruded mesoblast; but while this may be true of the vitreous humour and the blood vessels which pass through it to the back of the lens, there are grounds for believing the hyaloid membrane to be derived by cuticular exfoliation from the ocular cup. The zonule of Zinn probably belongs to the same set of parts.

The **eyelids** make their appearance gradually as folds of integument, subsequently to the formation of the globe in the third month of fœtal life. When they have met together in front of the eye, their edges become closely glued together by an epithelial exudation which is removed a short time before birth.

The **lachrymal canal** may be regarded as a persistently open part of the fissure between the lateral nasal process and the maxillary lobe of the embryo.

The first discovery of the mode of development of the eye as it is now generally understood was made by Huschke in 1832, and was published in Meckel's Archiv. for that year. In addition to the systematic works on Development, the reader is referred to the special treatises mentioned in the Bibliography.

II. THE EAR.

Primary Development.—The most important part of the organ of hearing originates by the involution of the epiblast from the external surface of the head in the region of the medulla oblongata. This is at first only a depression of a thickened part of the epiblast; but the depression soon deepening, and, its aperture towards the surface rapidly narrowing, it assumes a flask-like form, and constitutes on each side the primary auditory or otic vesicle.

This involution of the auditory vesicle takes place somewhat later than the evolution of the medullary vesicle of the eye, and differs from it in taking place secondarily from the epiblastic surface of the head, and not in immediate connection with the brain. The auditory vesicle is situated opposite the dorsal end of the hyoidean arch. The original aperture, which is directed backwards, is soon closed externally, but in the interior a vestige of it remains for a considerable time as the *recessus labyrinthi*, which corresponds to the aqueduct of the vestibule of later life.

Fig. 756.

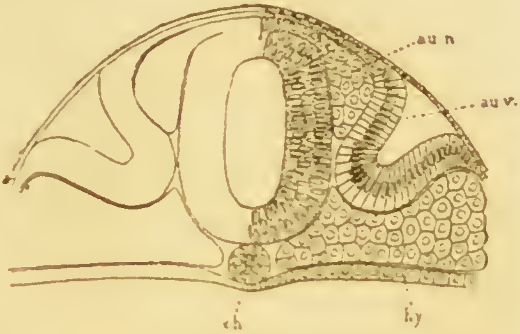


Fig. 756.—SECTION THROUGH THE HEAD OF A LEPIDOSTEUS EMBRYO OF AN EARLY PERIOD. (From Balfour.)

au.v, auditory vesicle ; *au.n*, auditory nerve ; *ch*, the notochord, immediately below the medulla oblongata ; *hy*, hypoblast. The nervous layer of the epiblast is seen to be distinct from the cuticular layer which is not involuted.

The primary otic vesicle, sinking down towards the basis of the cranium, becomes imbedded in the formative mesoblastic tissue lying between the basi-occipital and alisphenoid matrices, and along with them undergoes chondrification and ossification at an early period, as has been already described under the development of the head.

Fig. 757.

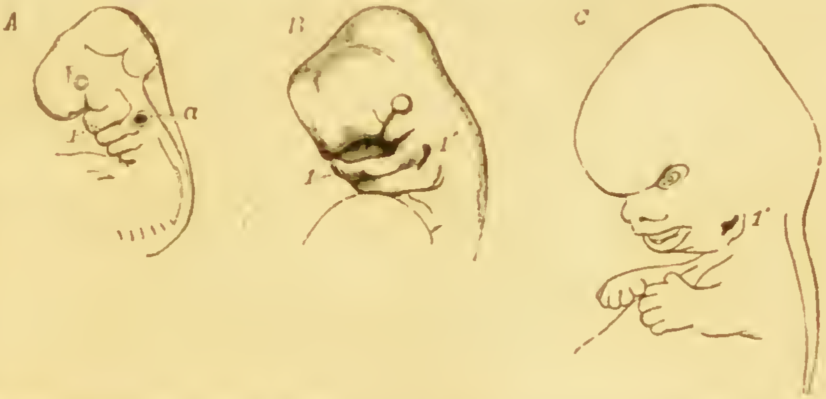


Fig. 757.—OUTLINES SHOWING THE EARLY CHANGES IN THE FORM OF THE HEAD OF THE HUMAN EMBRYO.

A, profile view of the head and fore part of the body of an embryo of about four weeks (from nature, $\frac{10}{1}$) : the five primary divisions of the brain are shown, together with the primary olfactory and optic depressions, and *a*, the auditory vesicle ; 1, marks the mandibular plate, and behind this are seen the three following plates with the corresponding pharyngeal clefts. *B*, from an embryo of about six weeks (from Ecker, $\frac{5}{1}$) : the cerebral hemispheres have become enlarged and begin to spread laterally : 1, the lower jaw ; 1′, the first pharyngeal cleft, now widening at the dorsal end, where it forms the meatus externus ; the second cleft is still visible, but the third and fourth clefts are closed and the corresponding arches have nearly disappeared. *C*, from a human fœtus of nine weeks (from nature, $\frac{2}{1}$) ; the features of the face are now roughly formed ; the outer part of the first pharyngeal cleft is now undergoing conversion into the meatus, and the auricle is beginning to rise at its external border.

The development of the organ of hearing, as a whole, consists of two very different sets of processes, viz., 1st, those connected with the formation of the nervous structure or labyrinth of the internal ear, and 2nd, those belonging to the development of the tympano-Eustachian passages and the accessory parts of the middle and outer ear. The first of these sets of changes occurs more immediately in the primary epiblastic vesicle in combination with the nervous elements derived from the medullary centre, and with the participation of the mesoblastic wall of the auditory capsule. In the second are involved the remarkable transformations of the first visceral arch and the hyomandibular cleft. In describing these changes reference will be made chiefly to mammals.

Labyrinth.—After the closure of the primary otic vesicle the extension of its cavity in different directions soon indicates the formation of the different parts of the future labyrinth. As the otic vesicle sinks more deeply into the base of the cranial wall, from being at first spherical it takes more of a pyriform shape, the pointed prolongation of the recessus labyrinthi stretching backwards or dorsally towards the place of the original involution from the surface.

Fig. 758.

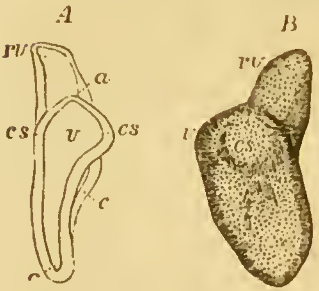


Fig. 758.—Labyrinth of the human fœtus of four weeks, magnified. (From Kölliker.)

A, from behind; B, from before; *v*, the vestibule; *rv*, recessus labyrinthi, giving rise later to the aqueduct of the vestibule; *cs*, commencement of the semicircular canals; *a*, upper dilatation, belonging perhaps to another semicircular canal; *c*, cochlea.

This narrower part soon becomes tubular, and stretches into the cranial wall, which it pierces, and in which, as the aqueduct of the vestibule, it becomes enclosed at a later period in the substance of the petrous bone. In clasmobranch fishes it remains open to the surface throughout life.

The auditory vesicle is also soon prolonged into an angular projection at its lower or ventral end, where it forms the commencement of the cochlear part of the labyrinth.

The two superior semicircular canals next appear as elongated elevations of the surface of the primary vesicle; the middle portion of each elevation becomes separated from the rest of the vesicle by the bending in of the walls under it, and thus the elevation is converted into a tube remaining open at both ends, which subsequently becomes elongated and acquires an ampullar dilatation; and while the cochlear extension continues to progress, and takes the form of a canal curving inwards, the external or horizontal semicircular canal begins to be formed much in the same manner as the two superior ones.

These changes are followed by a marked constriction of the main part of the vesicle on its inner side near the cochlear canal, which, gradually increasing, at last completely cuts off the part which afterwards becomes the *saccule* from the remaining larger portion which forms the *utricle.* A constriction also takes place in the vesicular wall between the saccule and the cochlear canal, leaving, however, these two cavities in communication by the narrow *canalis reuniens.*

The same constriction which separated the saccule and utricle leads to the division of the end of the recessus labyrinthi into two tubes, one of which now opens into each of these cavities.

The anterior or ventral part of the membranous labyrinth which is to form the foundation of the cochlea in mammals becomes soon elongated into a tube which is gradually bent inwards and coiled upon itself from left to right, at last to the extent of two and a half turns, and on the hollow side of this spiral there is now formed a double ridge of thickened epithelium which at a later stage is converted into the organ of Corti and the structures connected with the lamina spiralis.

Fig. 759.

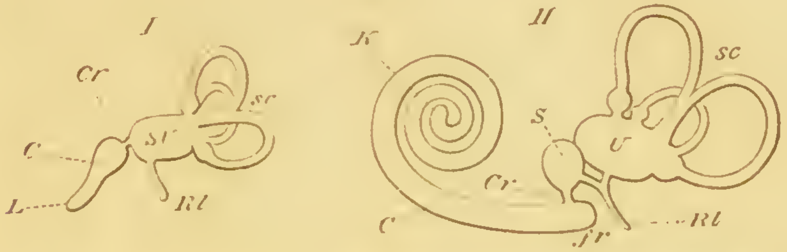


Fig. 759.—DIAGRAMS OF THE MEMBRANOUS LABYRINTH (after Gegenbaur.)

I, in a bird ; II, in mammals ; *sc*, semicircular canals ; U, utricle ; S, saccule ; (SU, combined in I) ; Rl, recessus labyrinthi ; *Cr*, canalis reuniens ; C, cochlea ; *fr*, its commencement at fenestra rotunda ; K, cupola ; L (in I) lagena.

Fig. 760.

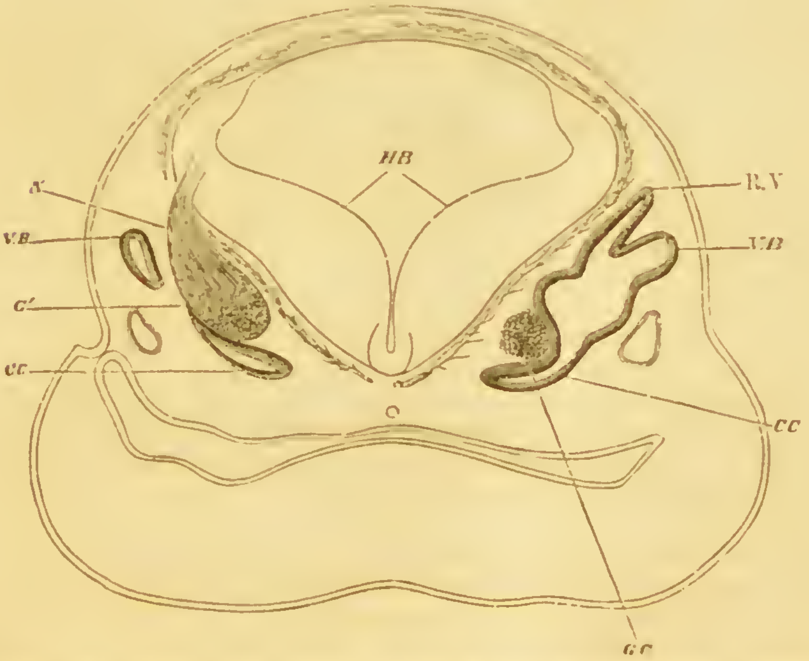


Fig. 760.—TRANSVERSE AND SLIGHTLY OBLIQUE SECTION OF THE HEAD OF A FŒTAL SHEEP, IN THE REGION OF THE HIND BRAIN (from Foster and Balfour after Boettcher.)

HB, inner surface of the thickened walls of the hind brain ; RV, recessus vestibuli ; VB, commencing vertical semicircular canal ; CC, canalis cochleæ, with the cavity of the primitive otic vesicle. On the left side parts only of these structures are seen ; GC, cochlear ganglion of the right side ; on the left side, G′, the ganglion, and N, the auditory nerve connected with the hind brain.

Meanwhile, however, it may be mentioned that the deposit of cartilage has advanced rapidly in the auditory capsule surrounding the vesicle, and this is soon followed by ossification of the capsule, as elsewhere stated. But between the cartilaginous wall and the various parts of the membranous labyrinth mesoblastic tissue has been interposed, which gives rise to the periosteum and to the lymph spaces which surround the membranous labyrinth and contain the fluid termed perilymph; while the various inflections of the labyrinthic cavity which are of epiblastic origin are filled with the endolymph.

Fig. 761.

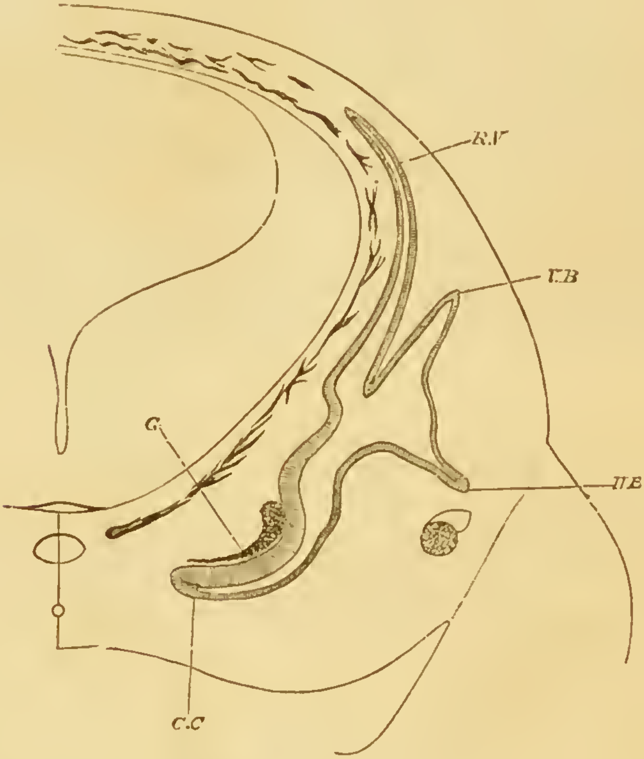


Fig. 761.—Transverse section of the head of a fœtal sheep of four-fifths of an inch in length. (From Foster and Balfour after Boettcher.)

RV, recessus vestibuli; VB, vertical semicircular canal; CC, cochlear canal; G, cochlear ganglion; HB, horizontal canal.

In the cochlea these spaces also exist, but in the special form of two tubular prolongations, one of which is situated on each side (above and below) of the cochlear canal, representing the first form of the scala vestibuli and scala tympani. Of these lymph passages the upper communicates with the vestibule, but the lower or scala tympani, which is somewhat later in being formed, is closed at the fenestra rotunda. The scalæ gradually progress along the coils of the cochlear canal till they reach its summit or *cupola*, which at first adheres to the wall of the capsule. From this, however, it is afterwards separated, when the two scalæ, having arrived at the summit, communicate with each other and intervene between the cupola and capsular wall.

The *lagena* of the uncoiled cochlea of birds corresponds to the cupola of the cochlear canal in mammals.

The lamina spiralis, with the organ of Corti and the upper and lower separating membranes (membrane of Reissner and membrana basilaris), are afterwards gradually developed outwards from the central pillar of the coiled cochlea; but we cannot attempt to give any detailed account of the formation of these minute and intricate structures.

Fig. 762.

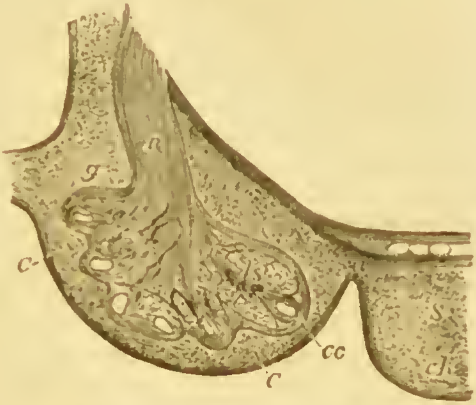


Fig. 762. — TRANSVERSE SECTION OF THE COCHLEA IN A FŒTAL CALF, MAGNIFIED. (From Kölliker.)

C, the wall of the cochlea, still cartilaginous; *cc*, canalis cochleæ; *ls*, placed in the tissue occupying the place of the scala vestibuli, indicates the lamina spiralis; *n*, the central cochlear nerve; *g*, the place of the spiral ganglion; S, the body of the sphenoid; *ch*, remains of chorda dorsalis.

It may, however, be mentioned that the auditory nerve when first formed is of large size and pierces the auditory capsule in two main divisions, vestibular and cochlear. The latter is remarkable as having upon it at an early period a large ganglion which exists before the cochlea becomes coiled, but which, being developed along with the lamina spiralis, takes the same coiled form (see fig. 761, and p. 466 of this volume).

The modiolus and spiral lamina, according to Kölliker, are ossified without the intervention of cartilage.

Accessory Parts of the Organ of Hearing.—The remarkable combination of the internal ear, or labyrinth, with certain other parts, to form the middle and external divisions of the acoustic apparatus, has already been adverted to in the account of the development of the face. Here, without going over the whole subject, we shall have only to refer shortly to some points of morphological interest connected with it.

The **tympano-Eustachian** passage is generally held, according to the view first propounded by Huschke, and confirmed by Reichert and others, to be developed in connection with the inner part of the hyo-mandibular or first postoral visceral cleft, while the meatus externus and pinna, or auricle, are formed on the outside; the membrana tympani, with its tympanic ring being interposed between, and the chain of ossicula with their accessory parts being formed in close relation with them. There can be no doubt that this view is substantially correct. But more recent researches, besides giving greater precision to the facts, have also modified in some degree the history of the process. From these researches it appears that the tympanic ring and the membrana tympani are developed close to the external surface, and that the meatus is therefore formed more immediately in connection with the outer skin, and by outward growth of the parts surrounding it, rather than by any actual depression.

Further, it is ascertained by the observations of A. Fraser that the hyo-mandibular cleft is from an early period almost completely closed in its dorsal portion by the intervention of the membrana tympani. This membrane consists of a layer of epiblast externally, of pharyngeal hypoblast internally, and, between these, of its fibrous and vascular parts, which are of mesoblastic origin.

According to the same author (No. 230), the malleus, as now agreed by all, is developed from the proximal part of the mandibular cartilage, and by observations on a variety of mammals he has shown that the incus is formed, according to the view advocated by Huxley and Parker, and contrary to that of Reichert, Salensky and others, in the proximal part of the hyoidean cartilage, which, from the first, is in close proximity to the mandibular cartilage. Fraser has further shown, in corroboration and extension of Salensky's observations (No. 229), that the stapes does not arise as a part of the hyoidean cartilage, or as a bud from the periotic wall, but as a circular deposit of cartilaginous cells round the stapedial artery, near to the fenestra ovalis, with which its base is afterwards connected.

With respect to the precise mode in which the tympanic cavity and Eustachian canal are formed in relation with the hyo-mandibular cleft, some difference of opinion has arisen among recent observers. Some, as Moldenhauer and Hunt (Nos. 222 and 228), have brought forward the view that these parts of the auditory passages are one or both of them new outgrowths from the pharynx, and others (Urbantschitsch), that they proceed from the mouth. But these authors do not give sufficient grounds for departing from the generally accepted opinion on this subject.

The **pinna** is gradually developed in connection with the integument on the posterior margin of the first visceral cleft. It is deserving of notice that congenital malformation of the external ear, with occlusion of the meatus and greater or less imperfection of the tympanic apparatus, are observed in connection with abnormal development of the deeper parts of the first and second visceral arches and the intermediate cleft (Allen Thomson, No. 231).

III. THE NOSE.

The organ of smelling, as was first pointed out by v. Baer, owes its origin, like the primary auditory vesicle and the crystalline lens of the eye, to a depression of the epiblast, and it differs from these involutions in remaining permanently open and in being greatly extended as a complicated cavity communicating with the exterior.

It has already been shown how closely the development of the nose is connected with, first, the extension of the axial part (trabeculæ) of the basi-facial axis ; second, the formation of the mouth, so that a part of the common cavity comes to be separated by the palate plates into the true buccal and lower nasal cavities ; and, third, more superficially and in front, with the external nasal wall.

The olfactory organ arises in all vertebrates at a very early period of embryonic life in the form of a depression of thickened epiblast from the forepart of the head.

The whole of the nasal fossæ, however complicated they may become in the labyrinthic form which they afterwards assume in many animals, are due to the involution of the epiblast of the original olfactory pits ; and the structure of the parts forming these inflections, as well as those associated with them, which are derived from mesoblastic sources, may be considered as essentially the same in different animals. In man these structures do not attain any great degree of complexity in the olfactory part, but in the human nose, as in animals, there is a marked difference in the form of that part of the labyrinth on which the olfactory nerve is distributed, and in the minute structure of its epithelium, from those of the lower part which forms the respiratory passage of the nose.

There is at first no olfactory lobe of the brain, and the nerve is solid. Marshall has shown that the olfactory lobe is formed at a comparatively late period, as at the end of the seventh day in the chick, and that this lobe arises by extension of the wall of the forebrain at the place where the nerves have previously sprouted out; that it contains a hollow prolonged from the general ventricular cavity, and carries the nerves on its most projecting part.

The development of the olfactory nerve has already been described.

III. DEVELOPMENT OF THE BLOOD-VASCULAR SYSTEM.

General Phenomena.—The heart and blood-vessels, with the blood-corpuscles and fluid, which from the first occupy their interior, take their origin entirely from the mesoblast, and the earlier rudiments of these vascular elements are situated in the deepest part of the visceral plate of the mesoblast, which was thence distinguished by Pander as the vascular layer of the blastoderm. At a later period it is probable that blood-vessels may arise throughout the whole of the mesoblast, both in its visceral and parietal divisions.

Fig. 763.

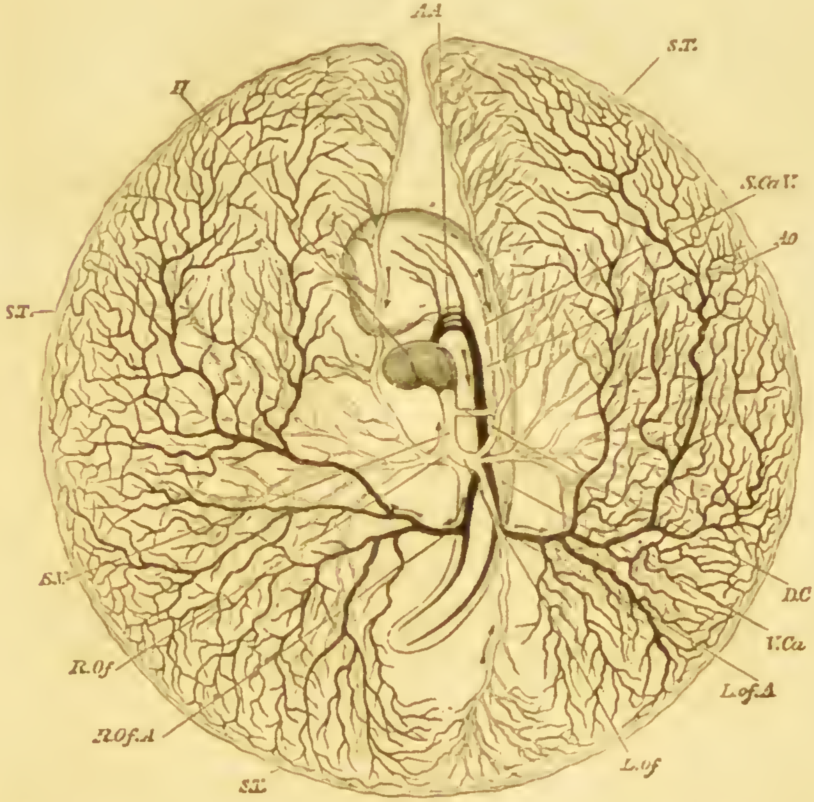


Fig. 763.—VASCULAR AREA OF THE YOLK-SAC OF THE CHICK ON THE THIRD DAY OF INCUBATION, SEEN FROM BELOW. MAGNIFIED ABOUT SIX DIAMETERS. (From Balfour.)

H, heart; *A.A*, three of the aortic arches of one side; connected with the uppermost are the external and internal carotid arteries; *AO*, dorsal aorta; *L.of.A*, left vitelline artery; *R.Of.A*, right; *S.T.*, Sinus terminalis: *L.Of*, left vitelline vein; *R.Of*, right; *S.V.*, sinus venosus; *D.C*, Ductus Cuvieri; *S.Ca.V*, superior cardinal vein: *V.Ca*, inferior; the arteries are shaded black, the veins are in outline; the embryo seen from its lower or left side is only faintly indicated.

The simultaneous origin of the blood-vessels and heart, partly within the body of the embryo and partly in the vascular area of the yolk, appears to be universal throughout the vertebrata, and is only modified in form in a few instances, as in some of the amphibia, by the undeveloped condition of the yolk sac. In the human ovum the same appears to be the first condition of the blood-vascular system, and as soon as before the fourteenth day from conception a simple tubular

Fig. 764.

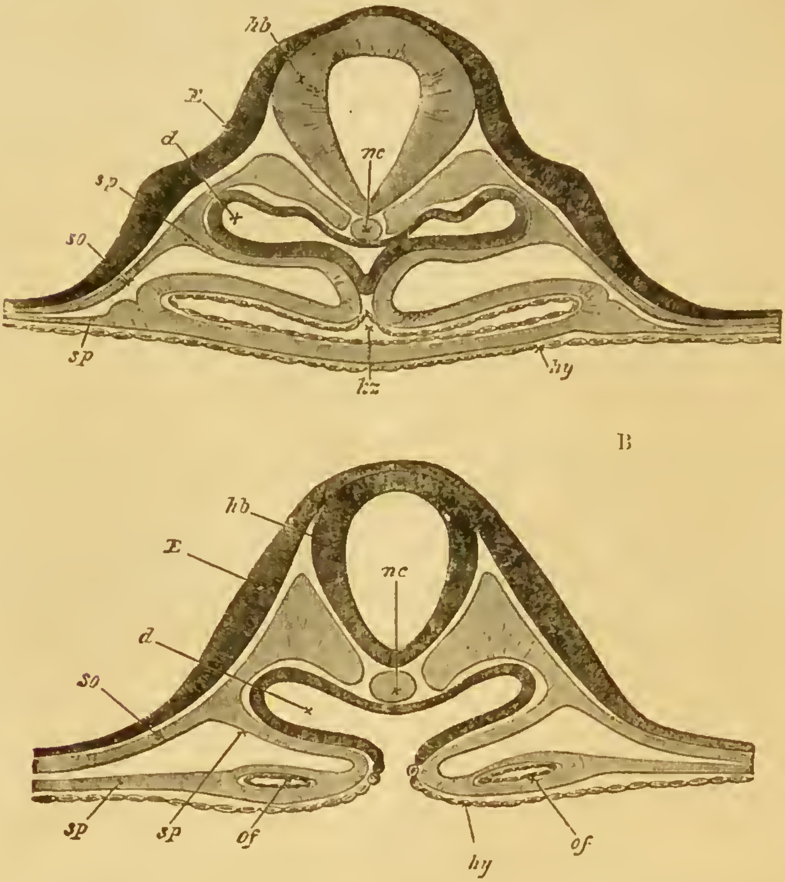


Fig. 764.—Diagrammatic views of two sections through the region of the hind-brain of an embryo-chick of about 36 hours, illustrating the formation of the heart. (From Balfour.)

In A, which is farthest forward, the parts of the heart have coalesced in the middle; in B, which is farther back, they are still widely separate.

hb, hind-brain; *nc*, notochord; *E*, epiblast; *so*, body-wall; *sp*, visceral wall; *d*, alimentary canal; *hy*, hypoblast; *hz*, heart; *of*, vitelline veins.

heart with incoming and outgoing vessels are formed in the body of the embryo, while the surface of the yolk or umbilical vesicle is occupied by ramified vessels and their capillary network.

The phenomena of vascular and blood formation have been observed with great minuteness and care, as they occur in the egg of the common fowl in the first half of the second day of incubation, and a sufficient amount of observations have been made in mammals and other animals to prove that the process is essentially the same in them all. The earlier steps of this process follow one another very rapidly, so that already by the 40th or 42nd hour in the fowl's egg the blood is propelled through the primary system of vessels by the rhythmic contractions of the tubular and as yet only cellular heart. At this period the parts of this very simple circulatory system consist of the blood fluid containing corpuscles in a rudimentary form : of blood-vessels, which are mainly spread over the vascular area and in less number within the body of the embryo ; and of a median tubular heart, into which the blood is brought from behind by two veins which collect it from the vascular area, and from which it is expelled anteriorly by two outgoing vessels which may be called arteries, though they do not as yet show any of the histological characters of these vessels.

The minuter steps of this process have been so fully described in the histological part of this work (p. 31 and p. 197), that it is unnecessary to do more at this place than to recall the fact that the blood-fluid and corpuscles originate by a change in the formative cells of the visceral mesoblast, which is accompanied by a differentiation of their protoplasm and multiplication of nuclei within spaces developed by internal vacuolization of the mesoblastic cells. The cells which give rise to the primary blood-vessels becoming hollow and radiated, and their processes being united together, capillary networks are produced by their dilatation into tubes and their intercommunication. The demarcation of the limits between the epithelial cells forming the walls of the primary capillary vessels is a later process, as also the addition of the cellular materials for the production of the middle and outer coats, and other tissues which give a more complex structure to the larger vessels : but nearly all the vessels consist at first only of endovascular elements, and have much of the form and structure of capillaries.

I. THE HEART.

The origin of the heart itself is in some respects histologically similar to that of the vessels, in so far that it is by the vacuolated formation of one or of two main tubular spaces within groups of mesoblastic cells that the cavity of the organ originates (see fig. 744, p. 838). But the formation of the walls of the primitive heart is due, not merely to the accumulation and differentiation of the mesoblastic cells in the region which it at first occupies, but is also effected by a folding of the mesoblastic layers round the cavity. In these folds two sets of

Fig. 765.

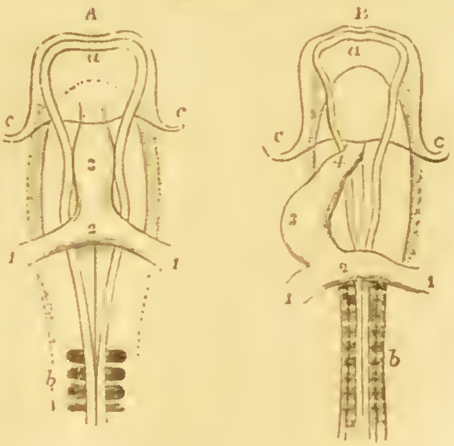


Fig. 765.—Outlines of the anterior half of the embryo chick viewed from below, showing the heart in its earlier stages of formation. (After Remak.) $\frac{20}{1}$

A, embryo of about 28 to 30 hours ; B, of about 36 to 40 hours ; *a*, anterior cerebral vesicle ; *b*, proto-vertebral segments ; *c*, cephalic fold ; 1, 1, vitelline or omphalo-mesenteric veins entering the heart posteriorly ; 2, their union in the auricle of the heart ; 3, the middle part of the tube corresponding to the ventricle ; 4 (in B) the arterial bulb.

cells are distinguishable from a very early period, viz., 1, those of a more delicate character and looser disposition in which the space or spaces for the heart's cavity are more immediately formed, and which afterwards range themselves round that cavity in the form of an endocardiac lining, and, 2, those forming a thicker layer which undergoes inflection, and which give rise to the muscular part of the wall. The pericardial covering arises by an extension of the wall of the body cavity which folds itself round each side of the commencing part of the heart.

Fig. 766.

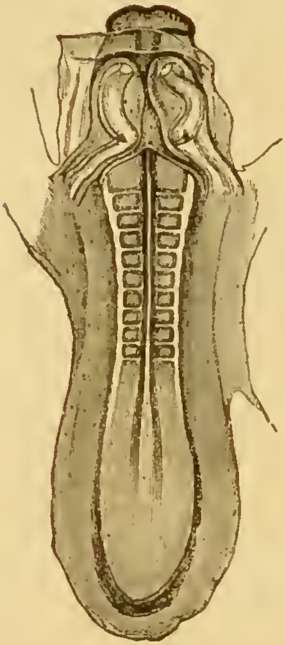


Fig. 767.

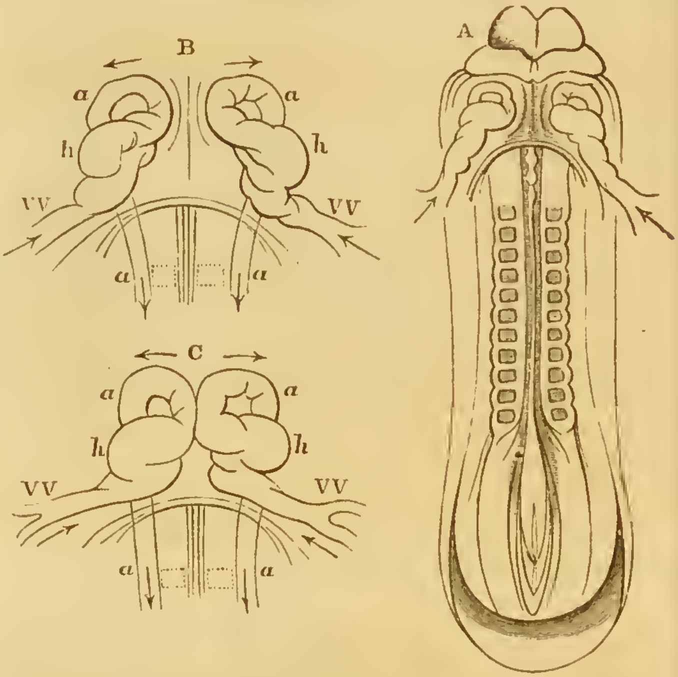


Fig. 766.—Embryo rabbit of eight days and eighteen hours, viewed from the ventral aspect. $\frac{24}{1}$. (From Kölliker.)

In the anterior part of the ventral wall on each side there is seen the separate rudiment of the heart, in the simple vascular tube of which are to be distinguished the hinder auricular, the middle ventricular and the anterior bulbous parts. There are ten proto-vertebral segments.

Fig. 767.—Views from below of the embryo-rabbit of nine days and three hours, showing the commencing heart in two stages. $\frac{22}{1}$. (A. T.)

These sketches, of which B and C are partly diagrammatic, were taken from two preparations given me by Professor Kölliker. A is the view from below of one of the embryoes in which the formation of the heart was least advanced, and of which an outline of the heart, &c., is repeated in B. In C, taken from the second preparation, the two halves of the heart are seen in the commencement of their coalescence. *h*, the part of the bent tube which becomes the ventricle; *a*, primitive aortic arches and separate descending aortas; VV, the vitelline veins entering the heart posteriorly. The arrows indicate the course of the blood.

There is, however, a considerable difference among animals in the form presented by the rudiments of the primitive heart, connected apparently with a difference in the rate of progress of the cephalic fold of the blastoderm which incloses the anterior part of the alimentary canal, and the median coalescence of the parts which give rise to the heart itself. Thus in certain animals, such as elasmobranchs, cyclostomata, ganoids, and amphibia, in which the closure of the cephalic fold is rapid, the deeper or endocardiac rudiments of the heart are collected into a mesial mass, and the cavity of the organ hollowed out in their interior is from the first single, and occupies a place on the ventral side of the pharynx immediately behind the branchial arches,

Fig. 768.

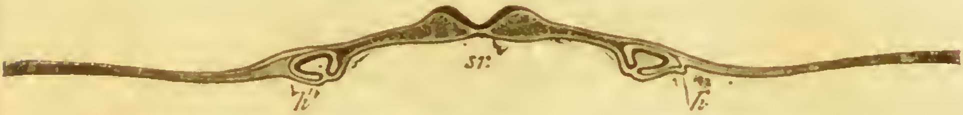


Fig. 768.—Transverse section through the head of an embryo rabbit of eight days and fourteen hours, with a part of the peripheral blastoderm. $\frac{45}{1}$. (From Kölliker.)

hh, rudiments of the heart; *sr*, pharyngeal groove.

where it receives the inflection of the mesoblastic cells, which form its muscular wall. But in others, such as mammals, in which the fact was first discovered by Hensen (No. 88), in osseous fishes, and to some extent also in birds, in which the enclosure of the pharyngeal cavity by the inflection of the cephalic fold is of later occurrence, the heart has at first the remarkable form of two tubes separated to some distance from each other, and the formation of the single and median cavity of the heart is due to the gradual approximation of these tubes and their coalescence

Fig. 769.

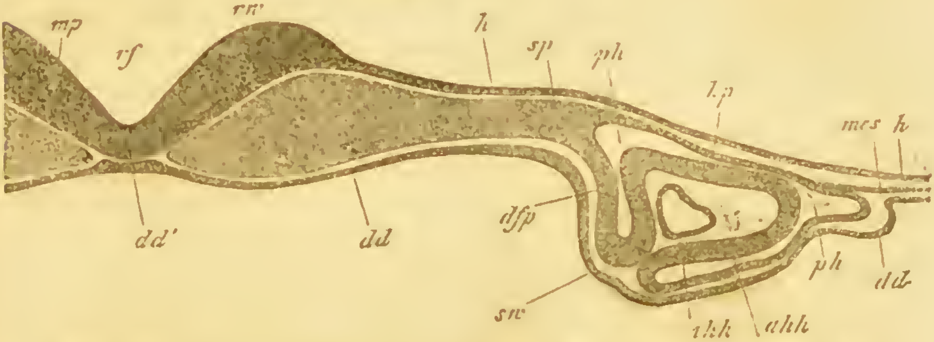


Fig. 769.—Part of the foregoing figure more highly magnified. $\frac{152}{1}$. (From Kölliker.)

rf, medullary groove; *rw*, dorsal ridge; *mp*, medullary plate and rudiment of the brain; *h*, epiblast; *hp*, parietal wall; *dfp*, visceral mesoblast, inflected into the outer wall of the heart *ahh*; *ihh*, inner or endovascular lining of the heart; *ph*, pericardial cavity; *mes*, mesoblast beyond the rudiments of the heart; *dd*, hypoblast; *dd'*, notochord; *sw*, lateral wall of the developing pharynx.

into one by the union and subsequent disappearance of the adjacent parts of their primitive walls. In the case of the heart being thus at first double, each tube receives posteriorly the large entering vein, and is prolonged anteriorly into the issuing vessel or artery; while in the median single heart, whether formed originally so, or by later fusion of two tubes, the posterior part receives the two entering veins, while the anterior part opens into the two primitive outgoing arteries.

The accompanying figures (768 & 769) from Kölliker will explain by a sectional view the manner in which in mammals the inflection of the two laminæ of the mesoblast gives rise to the walls of the separate components of the heart and the primary right and left compartments of the pericardium. The endocardiac lining (*ihh*) is derived from the deeper part of the visceral mesoblast.

Fig. 770.

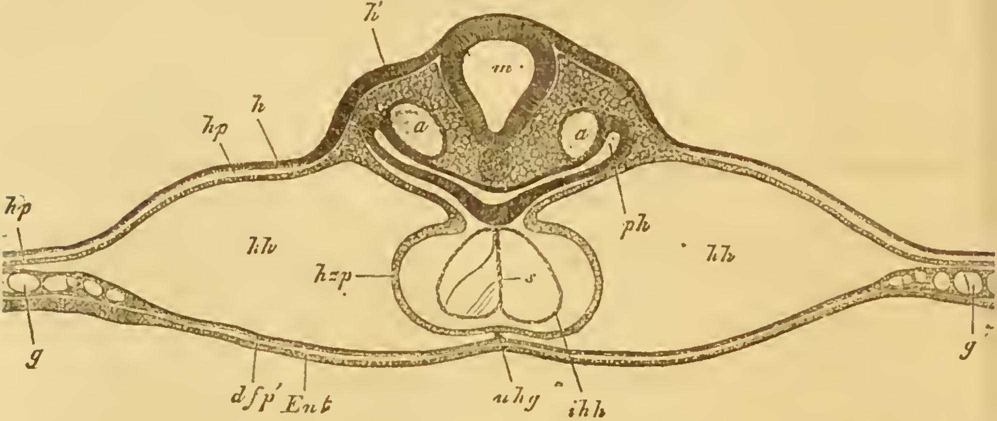


Fig. 770.—Transverse section through the region of the heart in an embryo-chick of 39 hours. $\frac{60}{1}$. (From Kölliker.)

m, medulla oblongata ; *a*, *a*, descending aortas ; *ph*, pharynx ; *h*, epiblast ; *h'*, thickening of the same where the auditory vesicle is to be formed ; *hp*, parietal mesoblast ; *hzp*, outer wall of the heart ; *ihh*, inner wall, the cavity still divided by a septum *s* ; *hh*, pericardial cavity ; *uhg*, ventral mesocardium produced temporarily by the reflection of the visceral mesoblast *hzp* into *dfp'* ; *g*, *g*, vessels in the visceral mesoblast ; *Ent*, hypoblast.

Fig. 771.

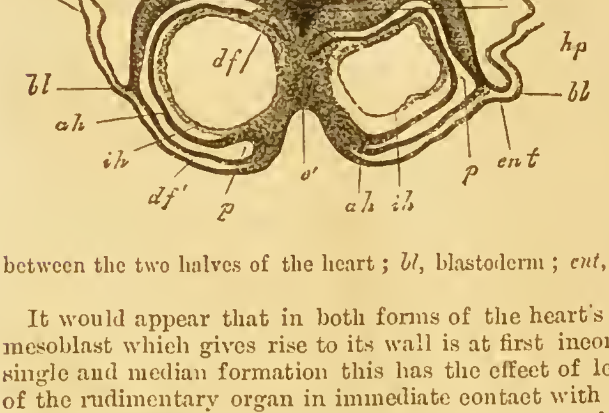


Fig. 771.—Transverse section through the region of the heart in a rabbit's embryo of nine days. $\frac{80}{1}$. (From Kölliker.)

jj, jugular veins ; *ao*, descending aortic roots ; *ph*, pharynx ; *hp*, body-wall reflected in *ect* ; *ih*, inner cellular lining of the still divided heart ; *ah*, outer wall of the heart ; *p*, pericardial cavity ; *df*, *df'*, visceral mesoblast ; *c'*, prolongation of the hypoblast of the foregut and the anterior wall of the pericardial cavity into the partition between the two halves of the heart ; *bl*, blastoderm ; *ent*, visceral wall.

It would appear that in both forms of the heart's origin the inflection of the mesoblast which gives rise to its wall is at first incomplete. In the case of the single and median formation this has the effect of leaving the endocardiac wall of the rudimentary organ in immediate contact with the hypoblast of the cephalic part of the alimentary cavity; but very soon the further inflection of the outer mesoblastic layer of cells completes the muscular and pericardial wall superiorly or on the dorsal side, leaving however there for a time a short septum at the place of meeting which constitutes a superior or dorsal mesocardium, while a similar septum exists for a time below as a ventral mesocardium.

The mode of formation of the heart in birds is in some degree intermediate between the two previously referred to, as the single organ arises by the coalescence of two tubes which are at first separate, but by the time these are formed the ventral wall of the pharynx is already advanced in its enclosure, so that it is almost impossible to detect the double form in the view of flat specimens of the bird's embryo. Hence, before the fact was ascertained by means of sections, the older observers all held the heart of the bird to originate as a single median organ.

The primitive veins or large vessels by which blood is carried into the posterior extremity of the rudimentary heart are the principal returning venous channels which collect the blood from the terminal sinus of the vascular area, while the two vessels which proceed from the anterior extremity form the first pair of aortic arches which bend over the side of the pharyngeal wall at the level of the mandibular arch and pass on dorsally in the body of the embryo below the vertebral somites as the two primitive aortæ, which afterwards coalesce to form the median aorta. To these further reference will be made later.

Among the further changes which the heart undergoes in the course of its progress from the simple form of a median symmetrical tube into its fuller state of development, one of the earliest may be attributed to the mere elongation of the tube, for the anterior and posterior extremities being fixed by the vascular connection to the body of the embryo, the elongating intervening part, which is not so attached, is necessarily thrown into a folded or curved shape, the middle part bulging ventrally, and taking usually a direction to the right side of the still prone and symmetrical embryo. This form of the heart has been observed in the human embryo of three weeks, corresponding in all respects to the heart of the bird or mammal at a parallel stage of advancement (see Fig. 772, A and B).

Fig. 772.

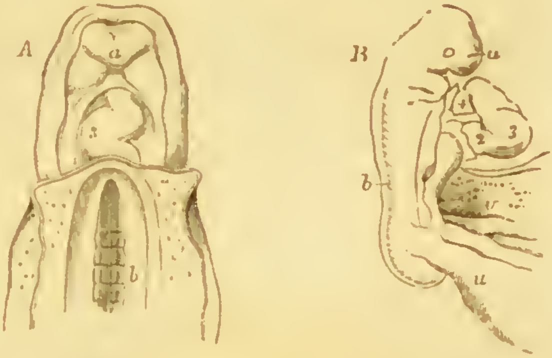


Fig. 772. — Human embryos at different early stages of development, showing the heart in its tubular condition.

A, upper half of the body of a human embryo of three weeks, viewed from the abdominal side (from Coste); *a*, frontal plate; *b*, protovertebræ, on which the primitive aortæ are lying; 3, the middle of the tube of the heart, below it the place of entrance of the great veins, above it the aortic bulb.

B, lateral view of a human embryo more advanced than that last referred to (from A. Thomson); *a*, the frontal part of the head; *b*, the vertebral column; *v*, the wide communication of the umbilical vesicle with the intestine; *u*, allantoic pedicle; 2, auricular part of the heart connected with the veins posteriorly; 3, ventricular part of the bent tube; 4, the aortic bulb; near the extremities of the tube the divided pericardium is seen.

As the development of the tubular heart progresses, the bend increases, and the venous is doubled back upon the arterial end. The tube also becomes divided by two slight constrictions into three portions, of which that originally posterior and receiving the veins is the widest, and constitutes the primitive auricle; the middle one, next in width, and most strongly bent upon itself, becomes the ventricular portion; and the third, situated anteriorly and retaining most the simple tubular form, is the arterial or aortic bulb.

Division into Single Auricle, Ventricle, and Arterial Bulb.—By a continued increase of the inflection of the heart-tube, a change in the relative position of the several parts is effected, so that the auricular cavity comes to be placed above or behind (dorsally) and to the left of the ventricular part, the veins being carried forwards along with it, while the arterial bulb is attached by its extremity in front to the neck of the embryo immediately below the visceral plates. There is as yet only a single passage through the heart, but the distinction of the auricular and ventricular cavities becomes more apparent, both by an increase in the diameter of each, and by the constriction which separates them, and by the much greater thickness acquired by the walls of the ventricular and bulbous parts as compared with the auricular portion.

Fig. 773.

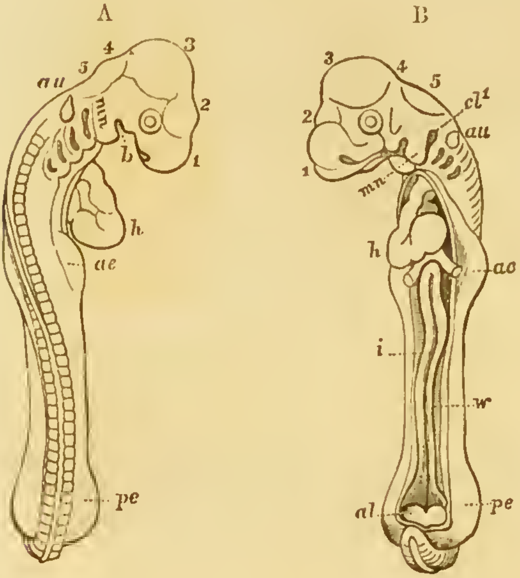


Fig. 773. — OUTLINES OF THE EMBRYO OF THE CHICK AT THE END OF THE THIRD DAY. $\frac{10}{1}$. (After His.)

A, dorsal and right side; B, ventral and left side; *h*, the heart. The other parts of the figure are explained elsewhere.

The three parts of the heart have now the appearance of being very closely twisted together. The ventricular part becomes considerably wider transversely, and the auricular part shows two projecting pouches, one on each side of the arterial bulb, which are the first indications of the future auricular appendages. At the same time the constriction between the auricular and ventricular parts increases considerably, and the constricted part elongating, produces what has been called the *canalis auricularis*.

Division of the Right and Left Cavities. Ventricles.—The next series of changes in the developing heart consists in the division of each original single cavity of the ventricle, auricle, and arterial bulb into two compartments, so as to form the right and left ventricles and auricles, and the stems of the pulmonary artery and aorta. The first of these changes occurs in the ventricular portion, and is to be seen in progress on the fourth day in the chick, and in the sixth and seventh week in the human embryo. The ventricular chamber of the heart increasing considerably in breadth, that part of it which ultimately becomes the apex of the heart is thrown towards the left side, and in most mammals, and especially in the human embryo, a blunt cleft or depression appears between this and the right part of the ventricle, which causes an external division into two portions corresponding to the future right and left ventricles; and if the interior of the ventricular cavity be examined at this time, there is perceived a crescentic partition rising from the lower border of the right wall and projecting into the cavity, at first narrow and placed opposite the external notch, but gradually growing more and more towards the auriculo-ventricular aperture. As development progresses the external division becomes more or less effaced, when the apex of the heart formed by the left ventricle becomes more pointed, and the whole heart takes somewhat of the conical form which belongs to its advanced condition; but in the adult heart the depression is still perceptible as the interventricular groove, which, as is well known, varies considerably in depth in different cases. In some animals, as the rabbit, the temporary external division of the ventricles is very apparent, while in others, as in ruminants, there is very little of the external notching to be seen, and in them, as in birds, the heart very early assumes the conical form. The dugong presents a remarkable example of the persistence of the complete external separation of the ventricles, and in the seal a tendency has been observed to the occasional occurrence of the same variety (Ecker, A. Thomson).

Fig. 774.

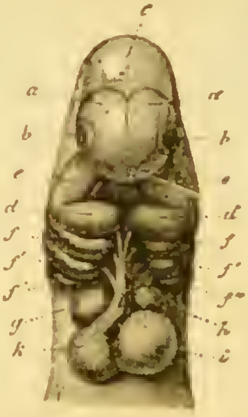


Fig. 774.—Head of the embryo of the dog with the heart seen from below. (From Kölliker, after Bischoff.) Magnified.

a, cerebral hemispheres; *b*, eyes; *c*, mid-brain; *d*, mandibular plates; *e*, superior maxillary processes; *f*, *f′*, *f″*, second, third, and fourth branchial or visceral plates; *g*, right, *h*, left auricle of the heart; *k*, right, *i*, left ventricle; *l*, aortic or arterial bulb, with three pairs of aortic or vascular arches proceeding from it.

Fig. 775.

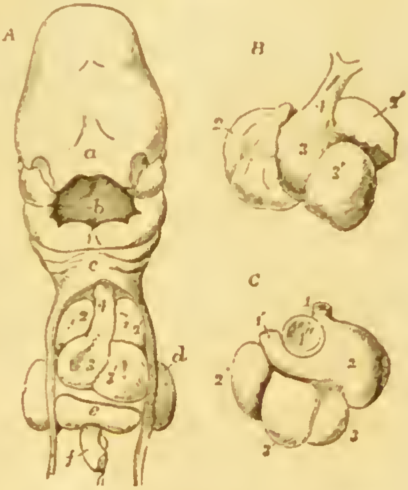


Fig. 775.—Shows the position and form of the heart in the human embryo from the fourth to the sixth week.

A, upper half of the body of a human embryo of nearly four weeks old (from Kölliker after Coste); B and C, anterior and posterior views of the heart of a human embryo of six weeks (from Kölliker after Ecker); *a*, frontal lappet; *b*, mouth; *c*, ventral ends of the second and third branchial arches; *d*, upper limb; *e*, liver; *f*, intestine cut short; 1, superior vena cava; 1′, left superior cava or brachio-cephalic connected with the coronary vein; 1″, opening of the inferior vena cava; 2, 2′, right and left auricles; 3, 3′, right and left ventricles; 4, aortic bulb.

The internal septum of the ventricles continuing to rise between the right and left divisions of the cavity, reaches at last the base, where it is placed in relation with both the auriculo-ventricular orifice and the root of the arterial bulb; but at this place there remains for a time a communication over the still free border of the septum between the right and left ventricles, which is interesting, as this is the seat of the abnormal communication between the right and left ventricles in almost all cases of malformation of the heart presenting that condition.

Division of the Auricles.—Although the auricular cavity presents externally some appearance of being divided into two at a period antecedent to the partition of the ventricles, in consequence of the formation of the right and left auricular appendages before mentioned, the internal division of the cavity does not take place till some time later, as on the fifth and sixth days in the chick, and in the eighth week in the human embryo. The auricular septum commences as an internal fold proceeding from the anterior wall of the common cavity, and starting from the septum of the ventricles, it grows backwards towards the entrance of the common vein or sinus, but stops short of it some distance. For a time, therefore, the veins enter the back part of the common auricular cavity. It is proper to explain, however, that, by the time at which the auricular septum is forming, the venous sinus has been modified so as to produce three veins entering the auricle at its back

Fig. 776.

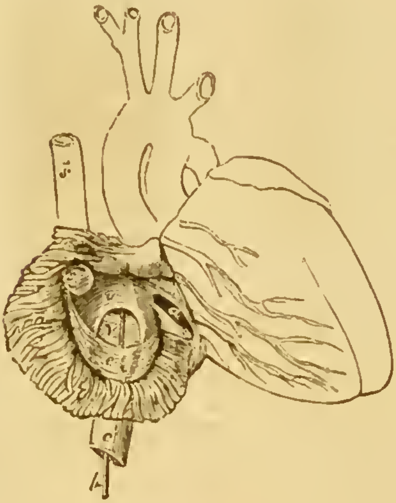


Fig. 776.—View of the front and right side of the fœtal heart, at four months, the right auricle being laid open. (From Kilian.)

a, the right auriculo-ventricular opening; *b*. a probe passed up the vena cava inferior and through the fossa ovalis and foramen ovale into the left auricle; *c*, vena cava inferior; *e*, Eustachian valve; *v*, valve of the foramen ovale; *s*, *s'*, vena cava superior.

Fig. 777.

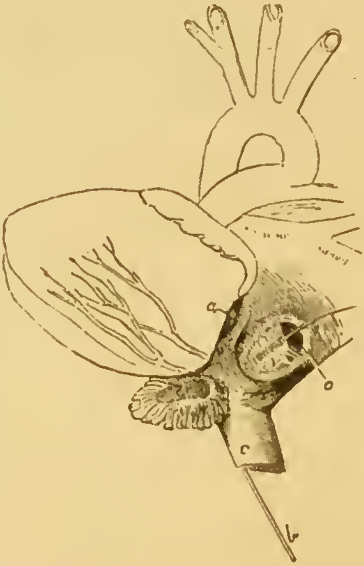


Fig. 777.—View of the posterior and left surface of the heart of a fœtus of four months, the left auricle being opened. (From Kilian.)

a, left auricular-ventricular orifice; *c*, inferior vena cava, through which a probe *b*, is passed from below, and thence by the foramen ovale into the left auricle; *c*, left auricular appendage laid open; *o*, valve of the foramen ovale seen to be attached to the left side of the annulus ovalis of the septum.

part. Of these, two correspond to the permanent right superior and the inferior cava veins, and the third to a left superior cava connected with what afterwards becomes the coronary sinus. For a time, all the three vessels open so as to communicate freely with the whole auricular cavity. But changes now occur which cause the left superior cava and the inferior cava to be directed towards the left side, while the right superior cava is placed more immediately in connection with the right part of the auricular cavity.

The auricular septum, in extending itself backwards, is not completed, but leaves an oval deficiency in its lower and middle part, as the *foramen ovale*, and the inferior cava opens immediately behind this aperture. Some time later, or in the human embryo in the course of the tenth or eleventh week, two new folds make their appearance in the auricles posteriorly. One of these, constituting the *Eustachian valve*, of a crescentic form, is placed to the right of the entrance of the inferior vena cava, and in the angle between it and the orifice of the left superior cava (or great coronary sinus). This fold, besides separating these two veins, and thus throwing the opening of the left superior cava into exclusive communication with the right auricle, runs forward into the annulus ovalis or border of the anterior auricular septum, deepening the entrance of the inferior cava into a groove close to the foramen ovale, and thus directing the blood entering by that vessel through the foramen into the left auricle. (Kilian, 237).

The other fold referred to advances from the posterior wall of the common auricle to meet the anterior auricular septum, but to the left of the border of the foramen ovale. To this border, however, it adheres as it grows forwards, and thus gradually fills up the floor of the fossa ovalis. Up to the middle of fœtal life, this posterior septum being incomplete, there is a direct passage from right to left through the foramen; but, after that period, the fold in question, having advanced beyond the anterior border of the annulus ovalis and lying to the left, does not adhere to this or the fore part of the annulus, but leaves a passage between, and appears as a crescentic fold in the left auricle, which, as it passes beyond the annulus, constitutes in the last three or four months a very perfect valve against the return of blood from the left into the right auricle.

Division of the Arterial Bulb.—The third important change occurring in the heart belongs to the arterial bulb, by which there are developed from this tube the first parts or main stems of the pulmonary artery and the aorta. Within the thick walls of this arterial tube there is at first only a single subcylindrical cavity, continued from the originally single ventricle; but, soon after the partition of the ventricular cavity has commenced, or in the human embryo of the seventh week, a division of the bulb by an independent process begins to take place. This consists in the projection inwards from the distal end of the bulb of a fold of the wall, involving at first only the inner and middle coats, not perceptible externally, and advancing more rapidly on the two sides than in the middle. The cavity of the bulb is thus divided into two channels, which may be described as respectively anterior and posterior, but which, from the spiral direction taken by the folds, are somewhat twisted on each other, so that the channel which at the ventricular end is placed anteriorly becomes connected with the right ventricle and forms the pulmonary stem, and that which is placed posteriorly becomes connected with the left ventricle and forms the commencement of the aorta. In the distal portion of the bulb, however, the pulmonary channel is situated to the left and posteriorly, and the aortic channel is to the right and most forwards; and at this end these channels are respectively connected with different aortic arches, giving rise to the permanent pulmonic and systemic vessels in the manner afterwards described. (Tonge, No. 248).

It is further to be noted that the partition of the bulb begins at the remote extremity between the fourth and fifth aortic arches, and advances towards the ventricles. There is a time, therefore, during which the ventricular septum, and the septum of the bulb, advancing towards each other, are incomplete and disunited; and from the difference in their general direction it is obvious that the septum of the bulb must be twisted upon itself, in order that it may finally unite and become continuous with that of the ventricles.

The completion of the partition of the aortic and pulmonary stems is afterwards effected by the progress of the division from within outwards through the external walls of the tubes; but the two vessels still remain united externally by a common envelope of pericardium.

The remarkable cases sometimes observed of abnormal transposition of the two great arterial stems from their natural connection with their respective ventricles may be explained by reference to the history of the development of the parts of the heart before given.

Formation of the Valves.—The formation of the auriculo-ventricular and semilunar valves takes place in the course of the second and third months in the human embryo. The semilunar valves of the aorta and pulmonary artery are formed simultaneously: and according to Tonge's observations in the chick, the plates or projections of the endocardiac lining which give rise to the valves are already formed before the septum of the bulb has reached the ventricle, and they arise at some distance from the ventricular orifices. The ventral and dorsal valves are the first to appear. Kölliker has observed these valves in the course of formation in the human embryo of seven weeks. The segments are at first of unequal size, one being much shorter than the other two. The sinuses are much later in being formed.

The auriculo-ventricular valves have been shown by the observations of Gegenbaur (No. 39), Bernays (No. 250), and Kölliker (No. 28, i.), to be formed out of plates which are originally part of the inner wall of the ventricles and auriculo-ventricular orifices. In connection with this it may be mentioned that the whole wall of the ventricles is in the earlier condition of the human heart, as in that of all animals, of a remarkable spongy or reticulated structure—a condition which remains persistent throughout life in most of the animals belonging to the three lower vertebrate classes; but in birds and mammals the reticulated structure is gradually lost by the solidification of the wall advancing from the outside inwards, and the columnæ carneæ and musculi papillares may be regarded as the vestiges of the reticulation internally.

The inner plates from which the auriculo-ventricular valves are formed contain at first a considerable amount of muscular substance, which afterwards in a great measure disappears.

In the latter changes, by which the inner plates are moulded into the form and structure of the valvular flaps, the upper or auricular part becomes fibrous, compact, and entire; the lower or ventricular part breaks up into the papillæ, which retain their muscularity and their attachment to the wall of the ventricles; while the intervening portion is more completely divided to form the thinner chordæ tendineæ in which the muscular structure is in a great measure or entirely lost. The division of the whole plates into the larger segments of the valves accompanies these changes.

The manner in which the pulmonary veins, which are formed separately in the lungs, come to be connected with the left auricle has not yet been ascertained.

No further important changes occur in the internal structure of the heart, but there are some which affect the external form and thickness of its walls. In early fœtal life the size of the heart bears a considerably greater proportion to that of the body than at a later period. At birth it is still proportionally large. For some time the auricular portion remains more voluminous than the ventricular, but in the latter half of fœtal life the permanent proportion is more nearly established. The walls of both ventricles are also thicker than in after life, and it is especially deserving of notice that the wall of the right is, up to near the time of birth, quite as thick as that of the left—a peculiarity which may be connected with the office of the right ventricle to propel the blood of the fœtus through the extended course of the ductus arteriosus, the descending aorta and the placental circulation.

II. DEVELOPMENT OF THE BLOOD-VESSELS.

The Principal Arteries. The Aorta.—The most interesting part of this history is that relating to the development of the aorta and the larger vessels arising from it.

In all vertebrates the arterial vessels proceeding from the ventral aortic bulb of the heart form five (and in some more) pairs of arches surrounding the anterior or pharyngeal part of the alimentary canal, and after a certain progress in development, uniting dorsally into the roots of the aorta of the trunk. At first, however, there is only one pair of these arches, and these are continued separately into the two vessels which represent the primitive state of the aorta.

It was first suggested by Serres, and subsequently proved by the writer of this chapter, by means of sections (No. 230, 1831), that the main aorta is formed by the median fusion of the two vessels previously separate. This fusion begins in the chick about the fortieth hour in the middle of the dorsal region, and extends forwards till it reaches the roots of the branchial arches, and backwards as far ultimately as the division into the iliac arteries. When this union reaches the place where the vitelline arteries pass out on each side, these vessels, each of which was previously the continuation merely of one of the primary main arteries, appear now as branches of a single and median aorta. The iliac are the next large vessels formed from the hinder part of the aorta. The first vessels belonging to these trunks are not, however, those of the lower limbs, for these do not yet exist; but rather the umbilical or hypogastric arteries, developed at a very early period in connection with the allantois, and subsequently attaining to a large size along with the growth of the placenta. As the limbs are formed, the arteries are developed in them which afterwards become the iliac divisions of the main aorta: but they are for a long time comparatively small, while the umbilical arteries are of very large size, so that, even up to the conclusion of fœtal life, these last appear to form the principal part of the two large vessels into which the aorta divides.

The relation of the process of mesial fusion of the originally double aorta to the occurrence of a permanent double canal in that vessel as a malformation.

described by Vrolik, Schröder van der Kolk, and Cruveilhier, and observed also by Allen Thomson, has already been referred to in vol. i., p. 350.

According to Serres, the vertebral arteries within the cranium are originally separate, and the basilar artery results from their mesial union or fusion in the same manner as occurs in the aorta; and the union of the two anterior cerebral arteries in the forepart of the circle of Willis is another example of the same process. It seems probable that the internal cross band observed by John Davy in the interior of the basilar artery may be a remnant of the septum or united walls of the two vertebral arteries.

Fig. 778.

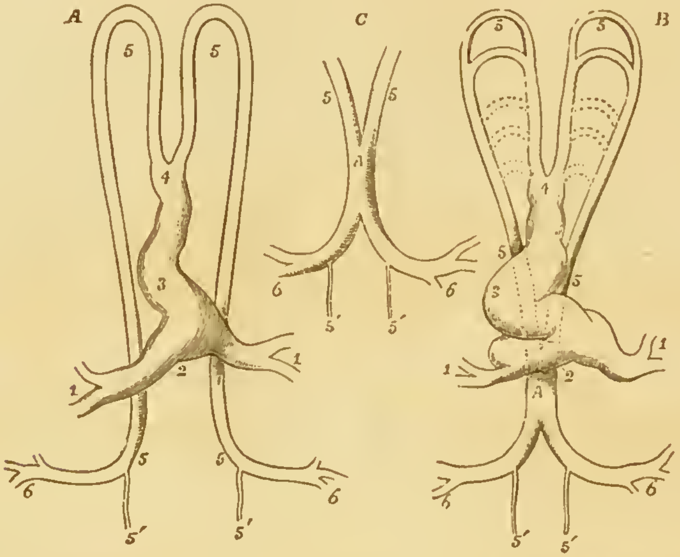


Fig. 778.—Diagrammatic outlines of the heart and primitive vessels of the embryo chick as seen from below and enlarged. (A. T.)

A, soon after the first establishment of the circulation; B, C, at a somewhat later period; 1, 1, the veins returning from the vascular area; 2, 3, 4, the heart, now in the form of a notched tube; 5, 5 (upper), the two primitive aortic arches; 5, 5 (lower), the primitive double aorta; A, the single or united aorta; 5′, 5′, the continuation of the double aortæ beyond the origin of the large omphalo-mesenteric arteries, 6, 6. The division above 4 is represented as carried rather too far down.

Aortic or Branchial Arches.—The two primitive arterial arches which lead into the dorsal aorta from the arterial bulb of the rudimentary heart, at the time of the establishment of the first circulation, are the most anterior of a series of five pairs of vascular arches which are developed in succession round this part of the pharynx; and which, since their discovery by Rathke in 1825 (No. 173), have been regarded with much interest, as corresponding with those which are the seat of development of the subdivided blood-vessels of the gills in fishes and amphibia. These vascular arches thus exhibit in the amniota, along with the branchial clefts and visceral arches, a typical resemblance to the structure of gills; and although no full development of these respiratory organs occurs in such animals, they give rise by their various transformations to the permanent pulmonary and aortic stems and the principal vessels which spring from them.

The form and position of the primitive aortic arches, up to the time of their transformation into permanent vessels, or their disappearance, are nearly the same in reptiles, birds, and mammals; and the main differences in the seat and distribution of the large permanent vessels are to be traced to changes in the patency and extent of growth of the several arches. The five pairs of arches do not all co-exist at the same time, for they are developed in succession from before backwards; and by the third day of incubation, or by the corresponding period of the fourth week in the human embryo, when the posterior arches have been formed, already the two anterior arches, beginning with the first one, have become partially obliterated. Each of the first four branchial arches occupies a place in the substance of the visceral arches, and in front of one of the pharyngeal clefts. The first or anterior is therefore situated in the mandibular arch, and in front of the tympano-Eustachian or hyomandibular cleft; and the fifth arterial arch is placed behind the fourth pharyngeal cleft and in the substance of the neck, in which there is no distinct arch in the higher animals, but which is the seat of a developed branchial bar in some aquatic vertebrates.

Fig. 779.

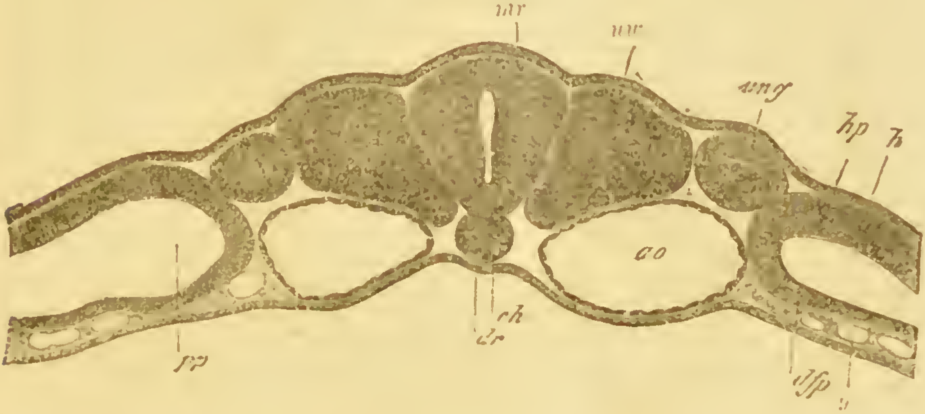


Fig. 779.—TRANSVERSE SECTION OF AN EMBRYO RABBIT, OF NINE DAYS AND TWO HOURS, IN THE MIDDLE DORSAL REGION. $\frac{135}{1}$. (From Kölliker.)

mr. medullary tube ; *uw*, protovertebral mass ; *h*, epiblast : *hp*, parietal mesoblast ; *dfp*, visceral division of the mesoblast ; *pp*, pleuro-peritoneal cavity between them ; *ung*, primitive segmental duct ; *g*, vessels in the visceral mesoblast ; *ch*, notochord ; *dr*, intestinal groove of the hypoblast.

The vessels forming the arterial arches are given off on each side in succession from two short canals, into which the primitive arterial bulb divides immediately in front of the place where it joins the neck. These may be named the ventral or anterior aortic roots; and similarly, when they have passed round the wall of the pharynx, the branchial arches unite in succession into a vessel on each side, thus forming the dorsal or posterior aortic roots.

On the third and fourth days in the chick, and from the fourth to the sixth week in the human embryo, there are still three complete pairs of arterial arches passing round the pharynx, and connected both before and behind with the anterior and posterior aortic roots previously mentioned. The transformations of these arches were in part traced by Von Baer and various other observers, but the fuller knowledge of their changes is due to the later researches of Rathke (No. 240, iv); and although some points are still left in doubt, their history may now be given from these observations, which receive interesting illustration from the investigation of the various examples of congenital malformation, the greater number of which are manifestly related to variations in the natural mode of development (see Fig. 780).

From these researches it appears that the permanent vessels owe their formation to the persistence of certain of the fœtal arches or parts of them, while other arches or portions of them become obliterated and disappear. Thus it is ascertained that in mammals the main aortic arch, which in the adult passes to the left of the trachea and gullet, is formed by the persistence of the fourth embryonic arterial arch of the left side, which not only remains patent, and is connected with the aortic stem of the arterial bulb, but by the increase of its width and the thickness of its walls keeps pace in its rate of growth with that of other parts of the body, so that it soon surpasses all the rest of the arches in its dimensions. In birds, however, the permanent aortic arch is on the right of the trachea and gullet, being formed by the persistence of the fourth embryonic arch of the right side; while, in all reptiles, as there are two permanent aortic arches, it is by the persistence of both the right and left fourth arches that the two aortas are produced, the right being that which is most directly connected with the systemic or left ventricle.

Fig. 780.

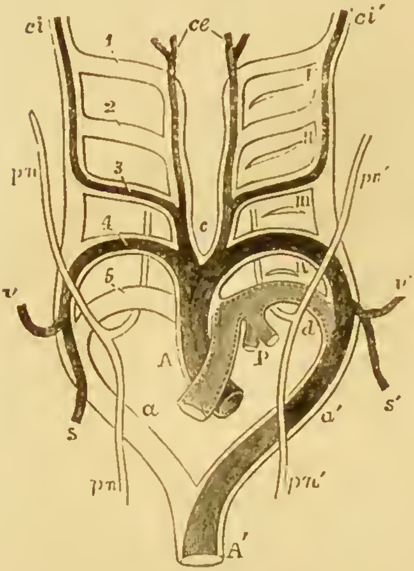


Fig. 780.—DIAGRAM OF THE AORTIC OR BRANCHIAL VASCULAR ARCHES OF THE MAMMAL, WITH THEIR TRANSFORMATIONS GIVING RISE TO THE PERMANENT ARTERIAL VESSELS. (After Rathke, slightly altered.)

A, P, primitive arterial stem or aortic bulb, now divided into A, the ascending part of the aortic arch, and P, the pulmonary: *a*, the right; *a′*, the left aortic root; A′, the descending aorta. On the right side, 1, 2, 3, 4, 5 indicate the five primitive arterial arches; on the left side, I, II, III, IV the four pharyngeal clefts, which, for the sake of clearness, have been omitted on the right side. It will be observed, that while the fourth and fifth pairs of arches rise from the part of the aortic bulb or stem, which is at first undivided, the first, second, and third pairs are branches above *c*, of a secondary stem on each side. The permanent systemic vessels are represented in deep shade, the pulmonary arteries lighter: the parts of the primitive arches which have only a temporary existence are drawn in outline only. *c*, placed between the permanent common carotid arteries; *cc*, the external carotid arteries; *ci*, *ci′*, the right and left internal carotid arteries; *s*, the right subclavian rising from the right aortic root beyond the fifth arch; *v*, the right vertebral from the same opposite the fourth arch; *v′*, *s′*, the left vertebral and subclavian arteries rising together from the left or permanent aortic root opposite the fourth arch; P, the pulmonary arteries rising together from the left fifth arch; *d*, the outer or back part of the left fifth arch, forming the ductus arteriosus; *pn*, *pn′*, the right and left pneumogastric nerves, descending in front of the aortic arches, with their recurrent branches represented diagrammatically as passing behind, with a view to illustrate the relations of these nerves respectively to the right subclavian artery (4) and the arch of the aorta and ductus arteriosus (*d*).

The pulmonary arteries of mammals would appear from Rathke's observations to be developed in connection with only one fœtal arterial arch—viz., the fifth of the left side—from the middle part of which they are formed as branches, and the whole fifth arch of the right side after a time undergoes atrophy and obliteration. The first part of the left fifth arch, becoming the common pulmonary artery, is connected with that division of the arterial bulb which is separated as the pulmonary stem; but the remote part of this arch also remains fully patent, and undergoing development equally with the rest of its extent, continues to lead into the *left* root of the aorta as ductus arteriosus Botalli, which serves to convey the blood from the right ventricle of the fœtal heart into the descending aorta, but becomes obliterated at the time of birth.

This duct is therefore in mammals due to a persistent condition of the fifth left branchial arch; but, in birds and reptiles, the process of transformation is somewhat different, for in them the right and left pulmonary arteries (excepting in those serpents in which there is only one lung developed) are formed in connection with the respective right and left fifth branchial arches, and there are thus two ductus arteriosi during fœtal life, the short one of the right side corresponding to that which is *left* or sinistral in mammals, and the longer one of the left side passing round the pharynx into the left aortic root. Both of these arches are obliterated at the time of the exclusion of the bird from the egg; but in some reptiles the ductus arteriosi remain permanently open during life.

The subclavian and vertebral arteries were shown by Rathke to spring from the posterior aortic roots at a place between the junction of the fourth and fifth arches. In mammals, the vessels on the left side are from the first in direct connection with the aortic root at the place which they permanently occupy: but upon the right side, as the fourth arch and the aortic root are obliterated posteriorly, the passage for blood from the aortic stem into the subclavian trunk is formed by the persistence of the forepart of the fourth right arch as far as the place where it meets the origin of the subclavian and vertebral arteries.

The common carotid trunks, occupying the region which afterwards becomes the neck, but which is at first absent or extremely short, are formed by the anterior divisions of the aortic roots; while the external carotid artery is due to the persistence of a channel in the continuation of each anterior aortic root, and the internal carotid artery arises from the persistence of the crossing third arch and the upper part of the posterior aortic root.

Thus it falls out that, in man and a certain number of mammals, an innominate artery is formed on the right side by the union of the first part of the fourth right aortic arch leading into the right subclavian with the right anterior aortic root which forms the common carotid: while, on the left side, the carotid and subclavian vessels rise separately from the permanent aortic arch in consequence of the distance between them in the original fœtal condition.

It does not come within the scope of this work to describe the further steps of development of these vessels, nor to enter into an explanation of the manner in which abnormal position of the arch of the aorta and its branches, or of the pulmonary arteries, may be supposed to arise. For further information on this subject the reader is referred to the short account of the varieties given in the description of the blood-vessels in the first volume of this work, as well as to the third volume of Henle's Handbuch, and to the special works of Tiedemann and Richard Quain on the arteries.

THE GREAT VEINS.

In the early embryo, before the development of the allantois, a right and a left vitelline (or omphalo-mesenteric) vein bring back the blood from the walls of the umbilical vesicle, and unite to form a short trunk, the meatus venosus, which is continued into the auricular extremity of the rudimentary heart.

In the first commencement of the allantoid circulation, or in the fourth week of fœtal life, two umbilical veins are seen coming from the placenta, and uniting to form a short trunk, which opens into the common vitelline vein. Very soon the right vitelline vein and right umbilical vein disappear. In connection with the common trunk of these veins, proceeding to the liver, two sets of vessels make their appearance in the early stage of its growth. Those furthest from the heart, named *venæ hepaticæ advehentes*, become the right and left divisions of the portal vein; the others are the hepatic veins, *venæ hepaticæ revehentes*. The portion of vessel intervening between those two sets of veins forms the *ductus venosus*, and the part above the hepatic vein, being subsequently joined by the ascending vena cava, forms the upper extremity of that vein. Into the remaining or left vitelline vein there open the mesenteric and splenic veins. The part above the latter forms the trunk of the portal vein; and the portion of vessel between the union of this with the umbilical vein and the origin of the venæ hepaticæ advehentes is so altered that the portal trunk opens into the commencement of the right vena advehens.

Fig. 781.

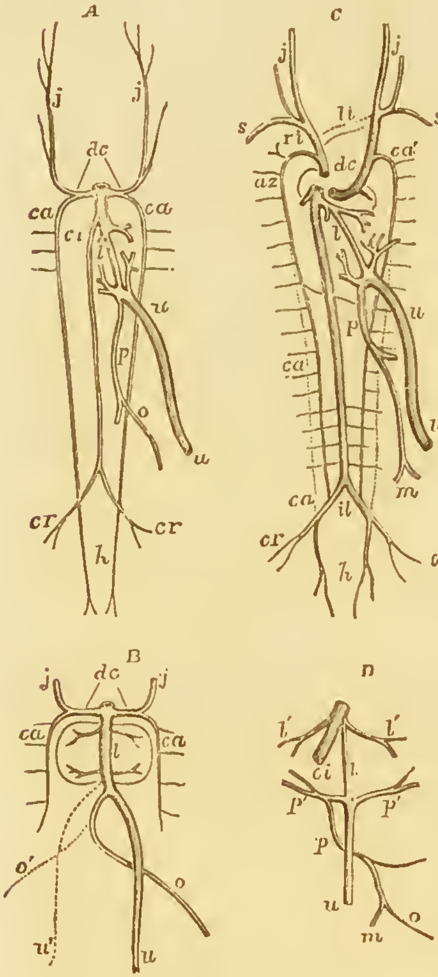


Fig. 781.—DIAGRAMS ILLUSTRATING THE DEVELOPMENT OF THE GREAT VEINS. (After Kölliker.)

A, plan of the principal veins of the fœtus of about four weeks, or soon after the first formation of the vessels of the liver and the vena cava inferior.

B, veins of the liver at a somewhat earlier period.

C, principal veins of the fœtus after the establishment of the placental circulation.

D, veins of the liver at the same period.

dc, the right and left ducts of Cuvier; *ca*, the right and left cardinal veins; *j*, *j*, the jugular veins; *s*, the subclavian veins; *az*, the azygos vein; *u*, the umbilical or left umbilical vein; *u'*, in B, the temporary right umbilical vein; *o*, the vitelline vein; *o'*, the right; *m*, the mesenteric veins; *p*, the portal vein; *P'*, *P'*, the venæ advehentes; *l*, the ductus venosus; *l'*, *l'*, the hepatic veins; *ci*, vena cava inferior; *il*, the division of the vena cava inferior into common iliac veins; *cr*, the external iliac or crural veins; *h*, the hypogastric or internal iliac veins, in the line of continuation of the primitive cardinal veins.

In C, *li*, in dotted lines, the transverse branch of communication between the jugular veins which forms the left brachio-cephalic vein; *ri*, the right brachio-cephalic vein; *ca'*, the remains of the left cardinal vein by which the superior intercostal veins fall into the left brachio-cephalic vein; above *P*, the obliquely crossing vein by which the hemiazygos joins the azygos vein.

At the time of the commencement of the placental circulation, two short transverse venous trunks, the *ducts of Cuvier*, open, one on each side, into the auricle of the heart. Each is formed by the union of a superior and an inferior vein, named respectively the *primitive jugular* and the *cardinal*.

The *primitive jugular* vein receives the blood from the cranial cavity by channels in front of the ear, which are subsequently obliterated: in the greater part of its extent it becomes the internal jugular vein; and near its lower end it receives small branches, which grow to be the external jugular and subclavian veins. The *cardinal veins* are the primitive vessels which return the blood from the Wolffian bodies, the vertebral column, and the parietes of the trunk. The inferior vena cava is a vessel of later development, which opens into the trunk of the umbilical and vitelline veins, above the venæ hepaticæ revehentes. The iliac veins, which unite to form the inferior vena cava, communicate with the cardinal veins. The inferior extremities of the cardinal veins are persistent as the internal iliac veins. Above the iliac veins the cardinal veins are obliterated in a considerable part of their course: their upper portions then become continuous with two new vessels, the *posterior vertebral veins* of Rathke, which receive the lumbar and intercostal twigs.

As development proceeds, the direction of the ducts of Cuvier is altered by the descent of the heart from the cervical into the thoracic region, and becomes the same as that of the primitive jugular veins. A communicating branch makes its appearance, directed transversely from the junction of the left subclavian and jugular veins, obliquely across the middle line to the right jugular; and further down in the dorsal region between the posterior vertebral veins a communicating branch passes obliquely across the middle line from right to left. The communicating branch between the primitive jugular veins is converted into the left brachio-cephalic or innominate vein. The portion of vessel between the right subclavian vein and the termination of the communicating branch becomes the right brachio-cephalic vein. The portion of the primitive jugular vein below the communicating vein, together with the right duct of Cuvier, forms

Fig. 782.

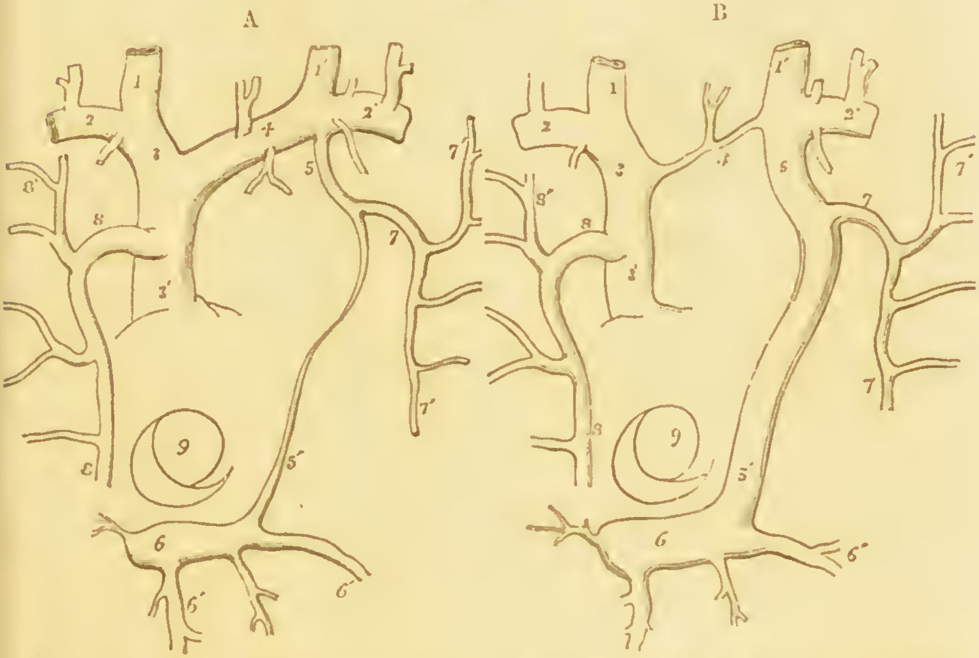


Fig. 782.—A and B.—DIAGRAMMATIC OUTLINES OF THE VESTIGE OF THE LEFT SUPERIOR CAVA AND OF A CASE OF ITS PERSISTENCE. (Sketched after Marshall.) $\frac{1}{2}$.

A, brachio-cephalic veins with the superior intercostal, azygos, and principal cardiac veins. (In this and in B the veins are supposed to be seen from before.)

B, the same in a case of persistence of the left superior cava, showing its communication with the sinus of the coronary vein. The views are supposed to be from before, the parts of the heart being removed or seen through.

1, 1′, the internal jugular veins; 2, 2′, subclavian veins; 3, right innominate; 3′, right or regular superior cava; 4, in A, the left innominate; in B, the transverse or communicating vein between the right and left superior venæ cavæ; 5, in A, the opening of the superior intercostal vein into the innominate; 5′, vestige of the left superior cava or duct of Cuvier; 5, 5′, in B, the left vena cava superior abnormally persistent, along with a contracted condition of 4, the communicating vein; 6, the sinus of the coronary vein; 6′, branches of the coronary veins; 7, the superior intercostal trunk of the left side, or left cardinal vein; 8, the principal azygos or right cardinal vein; 7′, 8′, some of the upper intercostal veins; 9, the opening of the inferior vena cava, with the Eustachian valve.

the vena cava superior, while the cardinal vein opening into it is the extremity of the great vena azygos. On the left side, the portion of the primitive jugular vein placed below the communicating branch, and the cardinal and posterior vertebral veins, together with the cross branch between the two posterior vertebral veins, are converted into the left superior intercostal and left superior and inferior azygos veins. The variability in the adult arrangement of these vessels depends on the different extent to which the originally continuous vessels are developed or atrophied at one point or another. The left duct of Cuvier is obliterated, except at its lower end, which always remains pervious as the coronary sinus. But even in the adult, traces of this vessel can always be recognised in the form of a fibrous band, or sometimes a narrow vein, which descends obliquely over the left auricle; and in front of the root of the left lung there remains a small fold of the serous membrane of the pericardium, the *vestigial fold*, so named by Marshall, to whom is due the first full elucidation of the nature and relations of the left primitive vena cava superior (No. 253).

Fig. 783.

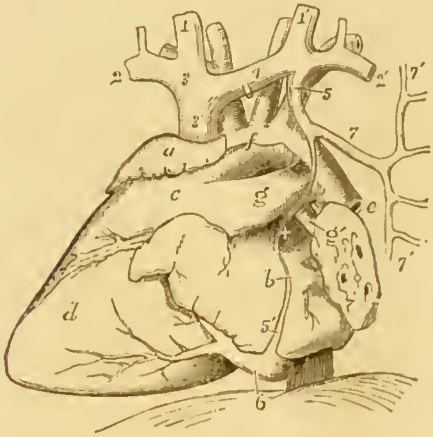


Fig. 783.—VIEW OF THE FŒTAL HEART AND GREAT VESSELS, FROM THE LEFT SIDE, TO SHOW THE VESTIGE OF THE LEFT SUPERIOR CAVA VEIN IN SITU. (This figure is planned after one of Marshall's, and slightly altered according to an original dissection.)

a, right auricle; *b*, left auricle and pulmonary veins; *c*, the conus arteriosus of the right ventricle; *d*, the left ventricle: *e*, descending aorta; +, vestigial fold of the pericardium; *f*, arch of the aorta, with a part of the pericardium remaining superiorly; *g*, main pulmonary artery and ductus arteriosus; *g'*, left pulmonary artery; 1, 1', right and left internal jugular veins; 2, 2', subclavian veins; 3, 3', right innominate and superior vena cava; 4, left innominate or communicating vein; 5, 5', remains of the left superior cava and duct of Cuvier, passing at + in the vestigial fold of the pericardium, joining the coronary sinus, 6, below, and receiving above the superior intercostal vein, 7; 7', 7', the upper and lower intercostal vein, joining into one.

The left duct of Cuvier has been observed persistent as a small vessel in the adult. Less frequently a right and a left innominate vein open separately into the right auricle, an arrangement which is also met with in birds and in certain mammals, and which results from the vessels of the left side being developed similarly to those of the right, while the cross branch remains small or absent (Quain, No. 243).

A case is recorded by Gruber (No. 254) in which the left vena azygos opened into the coronary sinus, and was met by a small vein descending from the union of the subclavian and jugular. Here, then, the jugular veins had been developed in the usual manner, while the left vena azygos continued to pour its blood into the duct of Cuvier.

III. PECULIARITIES OF THE FŒTAL ORGANS OF CIRCULATION.

It may be useful here to recapitulate shortly the peculiarities of structure existing in the advanced stage of the formation of the fœtal organs of circulation, with reference to their influence in determining the course of the blood during intra-uterine life, and the changes which occur in them upon the establishment of pulmonary respiration at birth.

1. The **foramen ovale** retains the form of a free oval opening in the septum auricularum up to the fourth month, but in the course of that month and the next the growth of the *valvular plate* or curtain, which fills up the floor of the fossa

ovalis. becomes complete. so that in the last three and a half months the blood can only pass from the right into the left auricle. but not in a contrary direction.

2. The **Eustachian Valve** constitutes a crescentic fold of the lining structure of the heart, which is so situated as to direct the blood entering the auricle by the inferior cava towards the opening of the foramen ovale.

Fig. 784.

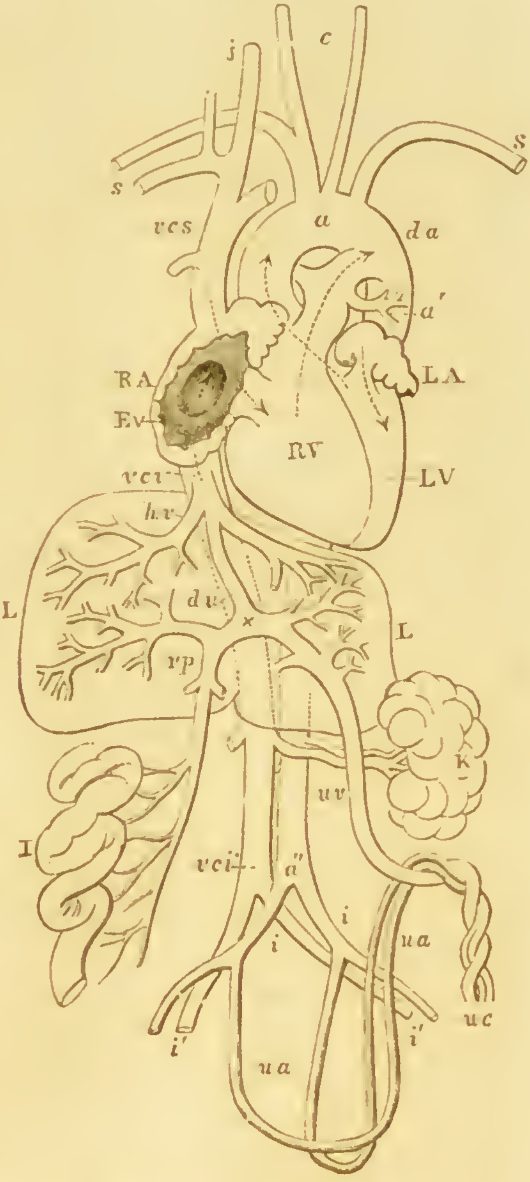


Fig. 784.—Diagrammatic outline of the organs of circulation in the fœtus of six months. (A. T.)

RA, right auricle of the heart; RV, right ventricle; LA, left auricle; Ev, eustachian valve; LV, left ventricle; L, liver; K, left kidney; I, portion of small intestine; *a*, arch of the aorta; *a'*, its dorsal part; *a''*, lower end; *vcs*, superior vena cava; *vci*, inferior vena where it joins the right auricle; *vci'*, its lower end; *s*, subclavian vessels; *j*, right jugular vein; *c*, common carotid arteries; four curved dotted arrow lines are carried through the aortic and pulmonary opening, and the auriculo-ventricular orifices; *da*, opposite to the one passing through the pulmonary artery, marks the place of the ductus arteriosus; a similar arrow line is shown passing from the vena cava inferior through the fossa ovalis of the right auricle, and the foramen ovale into the left auricle; *hv*, the hepatic veins; *vp*, vena portæ; *x* to *vci*, the ductus venosus; *uv*, the umbilical vein; *ua*, umbilical arteries; *uc*, umbilical cord cut short; *i i'*, iliac vessels.

3. The **ductus arteriosus** establishes a communication between the main pulmonary artery and the aorta, by which the blood from the right ventricle is carried mainly into the dorsal aorta.

4. **Umbilical Vessels.**—The two large hypogastric or *umbilical arteries*, prolonged from the iliac arteries, passing out of the body of the fœtus, proceed along the umbilical cord, to be distributed in the fœtal portion of the placenta. From the placenta the blood is returned by the umbilical vein, which, after entering the abdomen, communicates by one branch with the portal vein of the liver, and is continued by another, named *ductus venosus*, into one of the hepatic veins, through which it joins the main stem of the vena cava inferior.

Course of the Blood in the Fœtus.—The right auricle of the fœtal heart receives blood from the two venæ cavæ and the coronary vein. The blood brought by the superior cava is simply the venous blood returned from the head and upper half of the body; whilst the inferior cava, which is considerably larger than the superior, conveys not only the blood from the lower half of the body, but also that which is returned from the placenta and from the liver. This latter stream of blood reaches the vena cava inferior, partly by a direct passage—the *ductus venosus*—and partly by the hepatic veins, which bring to the vena cava inferior all the blood circulating through the liver, whether derived from the supply of placental blood entering that organ by the umbilical vein, or proceeding from the vena portæ or hepatic artery.

The blood of the superior vena cava, passing from the right auricle into the right ventricle, is thence propelled into the trunk of the pulmonary artery. A small part of it is distributed through the branches of that vessel to the lungs, and returns by the pulmonary veins to the left auricle; but, as these vessels remain comparatively undilated up to the time of birth, by far the larger part passes through the ductus arteriosus into the dorsal aorta, and is thence distributed in part to the lower half of the body and the viscera, and in part is conveyed along the umbilical arteries to the placenta. From these several organs it is returned by the vena cava inferior, the venæ portæ, and the umbilical vein; and, as already noticed, reaches the right auricle through the trunk of the inferior cava.

Of the blood entering the heart by the inferior vena cava, only a small part is mingled with that of the superior cava, so as to pass into the right ventricle; by far the larger portion, directed by the Eustachian valve through the foramen ovale, flows into the left auricle, and thence, together with the small quantity of blood returned from the lungs by the pulmonary veins, passes into the left ventricle, from whence it is sent into the arch of the aorta, to be distributed almost entirely to the head and upper limbs.

Sabatier was the first to call attention particularly to the action of the Eustachian valve in separating the currents of blood entering the right auricle by the superior and inferior venæ cavæ (No. 236). This separation, as well as that occurring between the currents passing through the aortic arch and the ductus arteriosus into the descending aorta, was illustrated experimentally by John Reid (No. 241). A striking confirmation of the extent to which the last mentioned division of the two currents of the fœtal blood may take place, without disturbance of the circulation up to the time of birth, is afforded by the examples of malformation in which a complete obliteration has existed in the aortic trunk immediately before the place of the union of the ductus arteriosus with the posterior part of the aortic arch.

CHANGES IN THE CIRCULATION AT BIRTH.

The changes which occur in the organs of circulation and respiration at birth, and which lead to the establishment of their permanent condition, are more immediately determined by the inflation of the lungs with air in the first respiration, the accompanying rapid dilatation of the pulmonary blood-vessels with a greater quantity of blood, and the interruption to the passage of blood through the placental circulation. These changes are speedily followed by shrinking and obliteration of the ductus arteriosus, in the space between the division of the right and left pulmonary arteries and its junction with the aorta, and of the umbilical arteries from the hypogastric trunk to the place of their issue from the body by the umbilical cord; by the cessation of the passage of blood through the foramen ovale, and somewhat later by the closure of that foramen, and by the obliteration of the umbilical vein as far as its entrance into the liver, and of the ductus venosus within that organ.

The process of obliteration of the arteries appears to depend at first mainly on the contraction of their coats, but this is very soon followed by a considerable thickening of their substance, reducing rapidly their internal passage to a narrow tube, and leading in a short time to final closure, even although the vessel may not present externally any considerable diminution of its diameter. It commences at birth, and is perceptible after a few respirations have occurred. It makes rapid progress in the first and second days, and by the third or fourth day the passage through the umbilical arteries is usually completely interrupted.

The ductus arteriosus is rarely found open after the eighth or tenth day, and by three weeks it has in almost all instances become completely impervious.

The process of closure in the veins is slower, there not being the same thickening or contraction of their coats; but they remain empty of blood and collapsed, and by the sixth or seventh day are generally closed.

Although blood ceases at once to pass through the foramen ovale from the moment of birth, or as soon as the left auricle becomes filled with the blood returning from the lungs, and the pressure within the two auricles is equalised, yet the actual closure of the foramen is more tardy than any of the other changes now referred to. It is gradually effected by the union of the forepart of the valvular fold forming the floor of the fossa ovalis with the margin of the annulus on the left side; but the crescentic margin is generally perceptible in the left auricle as a free border beyond the place of union, and not unfrequently the union remains incomplete, so that a probe may be passed through the reduced aperture. In many cases a wider aperture remains for more or less of the first year of infancy, and in certain instances there is such a failure of the union of the valve as to allow of the continued passage of venous blood, especially when the circulation is disturbed by over-exertion, from the right to the left auricle, as occurs in the malformation attending the morbus cœruleus.

LYMPHATIC SYSTEM.

Closely connected with the blood-vascular system, and also arising from the mesoblast, are the less conspicuous and sometimes rather indefinite components of the lymphatic system, consisting of the lymphatic vessels, glands, and the lymph spaces, the histological development of which has been referred to in the first part of this volume (p. 208).

Like the bloodvessels, the lymphatic vessels are intimately associated with the connective tissue, and they take their origin in a somewhat similar manner in spaces which are formed in the primitive blastema. It is also an interesting fact that these vessels are in frequent communication with the intermesoblastic space or pleuro-peritoneal cavity.

All the lymphatic vessels are at first similar to capillary bloodvessels, being lined only by flat epithelium; and many of them, though of some size, do not pass beyond this stage, while others acquire fibrous, contractile, and adventitious coats in a manner exactly the same as do the arteries or veins.

The lymphatic glands consist at first of networks of lymphatic vessels and spaces having numerous lymph cells produced within them; but later they have added to them connective tissue elements and bloodvessels in considerable quantity.

The Spleen.—There is perhaps none of the organs which have been ranked as vascular glands which so well deserves the name as the spleen, for it appears to be closely associated with both the lymphatic and the blood-vascular systems. It is not formed at a very early stage of development, but begins to appear in the human embryo in the latter half of the second month. It is developed in the substance of the mesogastrium, and is at first in close connection with the pancreas, but without any hypoblastic evolution, and proceeding entirely from mesoblast, apparently from the same mass as that in which the pancreas takes its origin (W. Müller, No. 256). Its progress is not rapid: it acquires vessels and trabecular fibres in the third month, and there is a large increase of the cells of the pulp; but the Malpighian corpuscles are only formed later, and are not distinctly seen till near the end of fœtal life. For the development of the Thyroid and Thymus Glands see p. 889.

IV. DEVELOPMENT OF THE ALIMENTARY CANAL AND ASSOCIATED ORGANS.

The parts of the body of which the development has been previously described all take their origin from either or both of the upper and middle layers of the blastoderm. Those which are now to be considered proceed, in the first instance, from the inflections and growth of the hypoblast or lower layer, with which, however, there are combined, in almost all of the organs, elements which are derived from the visceral layer of the mesoblast. These organs consist of the alimentary canal, with its integral and accessory glands, such as the liver and pancreas, the respiratory organs, the larynx, trachea, and lungs, the serous coverings of pleuræ and peritoneum, &c.

Primary Development.—Mesenteron.—The principal part of the alimentary canal is formed at first by a simple inflection of the hypoblast, and its wall then consists of no more than the epithelial cells derived from that layer of the blastoderm. In the most of its extent, however, this epithelial wall has acquired considerable thickness as compared with the part of the hypoblast external to the body of the embryo.

The primary digestive cavity of birds and mammals, as it extends from one end of the embryo to the other below the vertebral axis, and not including the buccal and anal portions derived from epiblastic involution, presents at first a manifest division into three parts. One of these, occupying the part of the embryo which is enclosed by the cephalic

Fig. 785.

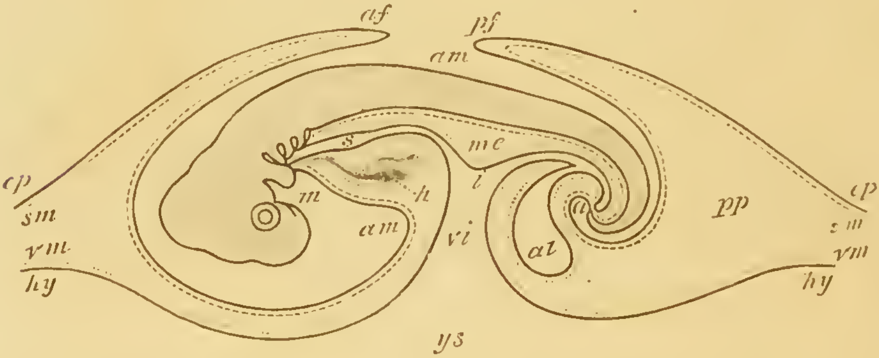


Fig. 785.—Enlarged diagrammatic outline of a longitudinal vertical section of the chick and neighbouring parts of the blastoderm on the fourth day. (A. T.)

ep, epiblast, and *sm*, somatic mesoblast, together forming the *somatic plate*; *hy*, hypoblast, and *vm*, visceral mesoblast, together forming the *visceral plate*; *af*, cephalic fold; *pf*, caudal fold of the amnion; *am*, cavity of the true amnion; *ys*, yolk-sack, leading by the vitello-intestinal aperture to *i*, the intestine; *s*, the stomach and pharynx; *a*, the future anus still closed; *m*, the buccal cavity or mouth formed in epiblast and still closed from the pharynx at the fauces, which are not shown; *me*, the mesentery; *al*, the allantoid vesicle communicating by its pedicle with the hinder intestine; *pp*, the space between the outer and inner folds of the amnion, which is an extension of the body cavity or pleuro-peritoneal space within the embryo between the somatic and visceral mesoblasts. The shaded part of the figure represents the head and trunk of the embryo in which the eye and the jaws with the branchial bars and clefts are indicated. The epiblast and hypoblast are drawn with entire lines, the somatic mesoblast with an interrupted and the visceral mesoblast with a dotted line.

fold, and which may be named the *foregut*, comprises the rudiments of the pharynx and gullet, the stomach and duodenum. The posterior division, which is comparatively short, occupies the caudal fold of the embryo, and corresponds mainly to the parts in the neighbourhood of the future anus, with a prolongation of the gut, which may be called post-anal or sub-caudal. Both of these parts have from the first a tubular form, and are closed respectively by the inflection of the whole blastodermic layers at the anterior and posterior extremities of the body. The middle division, or that in which the greater part of the small and large intestines will afterwards be formed, has primarily the form of a long and wide groove, lying close below the vertebral bodies, and leading at its opposite ends into the cephalic and caudal portions of the gut; it is freely open throughout on its ventral aspect into the cavity of the yolk-sac, with the blastodermic walls of which, as formerly described, the constituents of the intestinal walls are directly continuous.

Fig. 786.

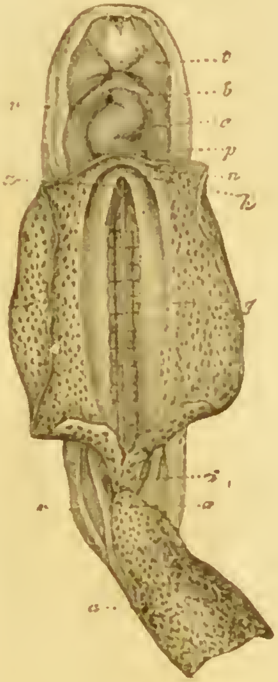


Fig. 786.—THE SAME EMBRYO AS IN FIG. 667 REMOVED FROM THE MEMBRANES, MORE HIGHLY MAGNIFIED AND SEEN FROM BELOW. (From Kölliker after Coste.)

a, allantois already forming an umbilical pedicle; *u*, urachus or stalk; *i*, hinder gut; *r*, amnion; *o*, yolk-sac; *g*, primitive aortas lying under the vertebral column, separated by the white line; *x*, wide opening of the intestine into the yolk-sac; *k*, place where the umbilical and omphalo-mesenteric veins meet and pass into the heart; *p*, pericardial cavity; *c*, heart; *h*, aorta; *t*, frontal process.

Foregut.—As development proceeds in the forepart of the alimentary canal, a change in its form manifests itself, by which one part, becoming dilated, forms the commencement of the stomach, while the others remain of smaller diameter as gullet and duodenum; and in connection with different parts of these the rudiments of the lungs, liver, and pancreas are first formed.

When the tubular parts of the gut have attained to some length, a change of position gradually accompanies their further development. While the œsophageal part remains comparatively straight, the dilated portion of the tube which forms the stomach turns over on its right side, so that the border which is connected to the vertebral column by the mesenteric fold (or true mesogastrium) comes to be turned to the left—the position of the tube being still vertical, like the stomach of some animals. By degrees it becomes more dilated, chiefly on what is now the left border but subsequently becomes the great curvature, and assumes more of the oblique position of the adult, carrying with it the mesogastrium, from which the great omentum is afterwards produced. A slight indication of the pylorus is seen at the third month. Upon the surface of the part of the canal which immediately succeeds the stomach, and which forms the duodenum, the rudiments of the liver, pancreas, and spleen are simultaneously deposited, in the manner stated in the description of the development of these organs.

Midgut.—Previously to the occurrence of the changes in the foregut mentioned above, the middle open part shortens, more and more of it being converted into the tubular intestine, and at last, as before explained, there remains only the narrow opening by which the gradually lengthening ductus vitello-intestinalis leads into the umbilical vesicle. The middle part of the intestinal canal has, when first produced, more or less the form of a straight tube lying close to the vertebral column; but, as soon as it increases in length, it is thrown into the shape of a loop bent downwards to the umbilicus —a change which is preceded and accompanied by the formation of the mesentery. The latter structure is undoubtedly entirely due to a proliferation and median union of mesoblastic elements, which, extending themselves between the mesoblast surrounding the notochord and the elongating gut, become developed into the vascular and other parts of the mesentery, as was long ago shown by Von Baer. The mesentery thus forms a mesial partition extending between the gut and the dorsal wall of the embryo, at first quite simple, but afterwards elongating, and becoming more complicated in proportion to the development of the intestinal tube. The mesoblast also, by its visceral division, furnishes the contractile, vascular, and connective tissue elements of the intestinal walls. The extent to which the glandular elements of the alimentary canal are supplied by the hypoblast, to which their origin was entirely attributed by Remak, or furnished rather by mesoblast from the protovertebral mass, as held by Schenk, is not yet fully determined.

Fig. 787.

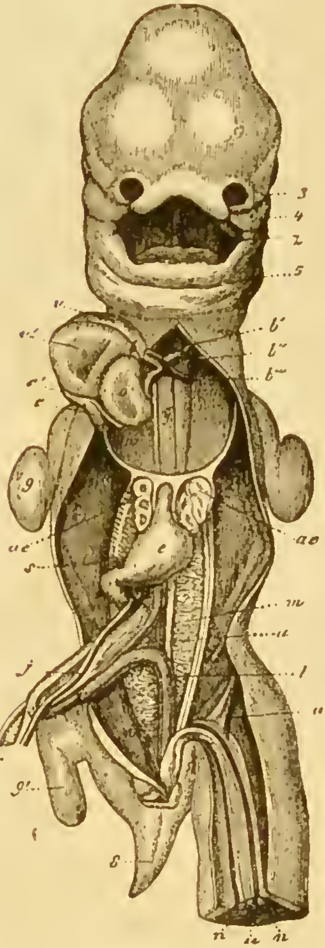


Fig. 787.—HUMAN EMBRYO OF THIRTY-FIVE DAYS SEEN FROM BEFORE. (From Kölliker after Coste.)

3, left external nasal process; 4, superior maxillary process; 5, lower maxillary process; *z*, tongue; *b*, aortic bulb; *b'*, third aortic arch or carotid stem; *b''*, fourth or main aortic arch; *b'''*, fifth arch or ductus Botalli; *c*, the superior cava and right azygos vein; *c'*, the common venous sinus of the heart; *c''*, the common stem of the left vena cava and left azygos; *o'*, left auricle of the heart; *v*, right; *v'*, left ventricle; *a e*, lungs; *e*, stomach; *j*, left omphalo-mesenteric vein; *s*, continuation of the same behind the pylorus, which becomes afterwards the vena portæ; *x*, vitello-intestinal duct; *a*, right omphalo-mesenteric artery; *m*, Wolffian body; *i*, rectum; *n*, umbilical artery; *u*, umbilical vein; 8, tail; 9, anterior; 9', posterior limb. The liver has been removed.

The place of transition from the small to the large intestine, which is soon indicated by the protrusion of the cæcum, is at a point just behind the apex or middle of the simple loop already mentioned as existing after the first elongation of the tubular gut. As the *small* intestine grows, the part behind the duodenum forms coils, some of which at first lie in a dilatation of the commencing umbilical cord (see fig. 789), but retire again into the abdomen about the twelfth week; afterwards, as it continues to elongate, its convolutions become more and more numerous.

The *large* intestine is at first less in calibre than the small. In the early embryo there is at first no cæcum; but this part of the bowel gradually grows out from the rest, forming at first a tube of uniform calibre, without any appearance of the vermiform appendix: subsequently the terminal part of the diverticulum ceases to grow in the same proportion as the rest, and narrows into the appendix, whilst the proximal part attains its full development. The cæcum first appears as a protrusion a little below the apex of the bend in the primitive intestinal canal, and, together with the commencing colon, and the coils of small intestine, is lodged for a time in the wide part of the umbilical cord already mentioned as being next the body of the embryo. The ileo-cæcal valve appears at the commencement of the third month. When the coils of intestine and the cæcum have retired from the umbilicus into the abdomen, the colon is at first entirely to the left of the convolutions of the small intestines, but subsequently the first part of the large intestine, together with the mesocolon, crosses over the upper part of the small intestine, at the junction of the duodenum and jejunum. The cæcum and transverse colon are then found in the middle of the abdomen just below the liver; some time later the cæcum descends to the right iliac fossa, and the parts are nearly in the same position as in the adult.

Fig. 788.

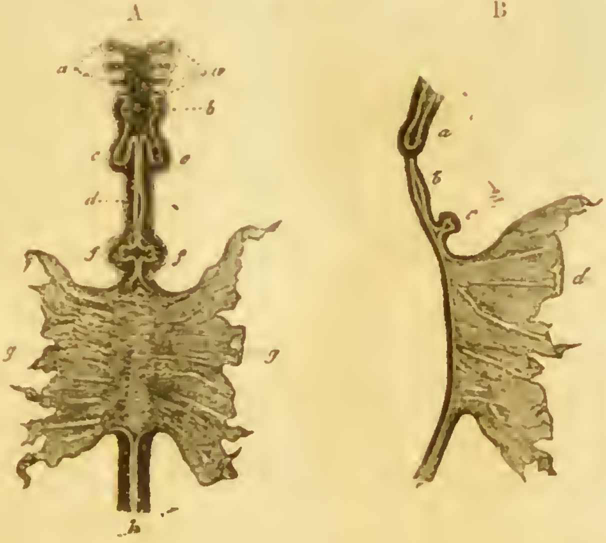


Fig. 788.—Early form of the alimentary canal (from Kölliker after Bischoff).

In A a front view, and in B an antero-posterior section are represented.

In A, *a*, four pharyngeal or visceral plates; *b*, the pharynx; *c*, *c*, the commencing lungs; *d*, the stomach; *f*, *f*, the diverticula connected with the formation of the liver; *g*, the yolk-sac into which the middle intestinal groove opens; *h*, the posterior part of the intestine. In B, *a*, the commencing lungs; *b*, the stomach; *c*, the liver; *d*, the yolk-sac.

At first, villous processes or folds of various lengths are formed throughout the whole canal. After a time these disappear in the stomach and large intestine, but remain persistent in the intermediate portions of the tube. According to Meckel, the villous processes are formed from larger folds, which become serrated at the edge, and are thus divided into separate villi.

Hindgut.—The formation of the hinder part of the gut is complicated with the development of the allantois, which arises as a projection or out-growth of the mesoblast and hypoblast from the lower wall of its terminal portion, and which is therefore in connection internally with the hypoblastic lining of the cloaca.

Fig. 789.

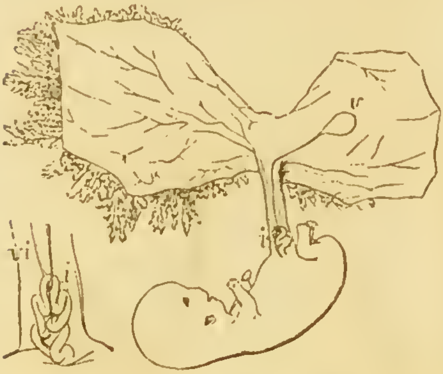


Fig. 789. — SKETCH OF THE HUMAN EMBRYO OF THE TENTH WEEK, SHOWING THE COIL OF INTESTINE IN THE UMBILICAL CORD. (A. T.)

The amnion and villous chorion have been opened and the embryo drawn aside from them; *v*, the umbilical vesicle or yolk-sac placed between the amnion and chorion, and connected with the coil of intestine, *i*, by a small or almost linear tube; the figure at the side represents the first part of the umbilical cord magnified; *i*, coil of intestine; *vi*, vitello-intestinal duct, alongside of which are seen omphalo-mesenteric blood-vessels.

Mesentery, Peritoneum and Diaphragm.—In the region of the pharynx and gullet the undivided mesoblast furnishes the outer coat of the alimentary canal, but in the stomach, and all the remainder of the gut, except at the anus, the separation of the two layers of mesoblast has taken place, and the visceral mesoblast furnishes the outer wall, together with the serous covering. In the thorax the right and left cavities remain distinct as the two pleuræ, while a portion still further forward is separated for the formation of the pericardium, and thus the gullet, as well as the lungs, is brought into relation with the pleuræ, and receives partial covering from them. The formation of the diaphragm, which does not at first exist, and which constitutes in mammals a partition between the thorax and abdomen, leads to the ultimate separation of the peritoneum from the pleuræ. Kölliker conjectures that the diaphragm may be formed by the advance of two halves from the dorsal and lateral regions, but the mode of origin of this partition is not yet sufficiently known (see Cadiat., No. 271), (His, No. 132, i. and ii.). Some examples of diaphragmatic hernia may be considered as arising from the persistence of the original connection between the two cavities. In the abdomen, also, the right and left peritoneal cavities are at first distinct, but when the intestine assumes a tubular form, these cavities are thrown into one across the middle plane of the body.

The peritoneum, like the rest of the lining of the body-cavity, is developed locally by superficial delamination from the mesoblast, and not from any special layer of formative tissue. The stomach is originally placed longitudinally in the abdomen, that part of it which afterwards forms the great curvature being situated dorsally and being attached by the simple mesogastrium. Very soon, a change of place occurs by which the pyloric part of the stomach and the duodenum pass to the right side, the left side of the primitive stomach thus coming to look ventrally and the right side dorsally. About the same time the mesogastrium is rapidly expanded and doubled upon itself so as to enclose a cavity, while a fold of peritoneum connected with the liver, and arising from the ventral border of the stomach which has now become the lesser curvature, contracts round the entrance to the great omental cavity (behind the stomach and within the omentum) so as to form the gastrohepatic omentum and the foramen of Winslow (as first shown by Joh. Müller in 1830). The dorsal fold of the great omentum has not at first any connection with the transverse colon or its mesocolon, and there can be no doubt that it is only at a later period that it comes to be so closely united with them as to have given rise to the view, quite inconsistent with the history of its development now stated, that the transverse colon is enclosed between the two posterior layers of the omentum.

The occurrence of umbilical hernia in its various degrees may be referred to the persistence of one or other of the fœtal conditions in which a greater or less portion of the intestinal canal is contained in the umbilical cord: and it has been shown that the most common form of abnormal diverticula from the small intestine is connected with the original opening of the ductus vitello-intestinalis into the ileum.

Fig. 790.

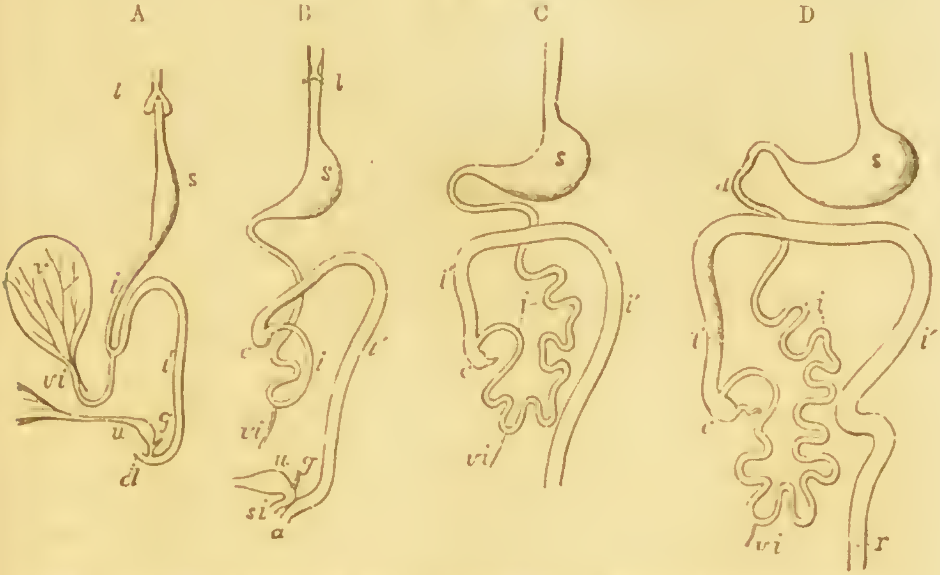


Fig. 790.—OUTLINE OF THE FORM AND POSITION OF THE ALIMENTARY CANAL IN SUCCESSIVE STAGES OF ITS DEVELOPMENT.

A, alimentary canal, &c., in an embryo of five weeks; B, at eight weeks; C, at ten weeks; D, at twelve weeks; *l*, the primitive lungs connected with the pharynx; *s*, the stomach; *d*, duodenum; *i*, the small intestine; *i′*, the large; *c*, the cæcum and vermiform appendage; *r*, the rectum; *cl*, in A, the cloaca; *a*, in B, the anus distinct from *si*, the sinus uro-genitalis; *v*, the yolk-sac; *vi*, the vitello-intestinal duct; *u*, the urinary bladder and urachus leading to the allantois; *g*, the genital ducts. In B, and C, the thickness of the colon is erroneously represented as greater than that of the ileum, and in C and D the cæcum as too far down and to the right.

Stomodæum.—The mouth, as elsewhere explained, is at first no part of the primitive alimentary canal, but is formed by involution of parts of the face, and receives, therefore, its lining membrane from epiblast. In this stage it has received the name of *stomodæum*. It is at first quite separated from the pharynx, which is the foremost part of the primitive alimentary canal, by the reflection of the layers of the blastoderm; and the communication which is later established between the mouth and pharynx at the posterior arch of the fauces is due to a solution of continuity in these layers, which occurs in the chick at the end of the fourth day of incubation, and has been observed at a corresponding period of development in several mammals. The aperture has at first the form of a vertical slit, which widens later as it becomes the opening from the pharynx into the common cavity of the nose and mouth. The diverticulum of the pituitary gland occupies the place which becomes the top of the permanent pharynx, but is formed in connection with the epiblastic or buccal, and not the hypoblastic or pharyngeal division of the alimentary passage (see fig. 705, A and B, *f*).

Proctodæum.—To the anal invagination of the epiblast, in so far as it is separate from the primitive hypoblastic part of the hind gut, the name of *proctodæum* has been given.

In mammals there is very little anal invagination of the epiblast; in birds it is more extended from the development of the *bursa Fabricii* in connection with it, and the opening of the gut into the anus occurs at a comparatively late period, or not till the fifteenth day (Kölliker). In the rabbit the opening takes place on the eleventh or twelfth day. The subcaudal or postanal portion of the gut shrinks and disappears even before the opening takes place. The terminal portion of the gut remains behind the allantoid pedicle, and the whole of the tissues which close it thinning rapidly away, perforation takes place so as to form the primitive anal, or rather the cloacal opening. The separation of the permanent anus from the urogenital orifice, which occurs in all mammals excepting the monotremata, is the result of a later process of development, to be referred to in the next section. (Gasser, No. 272.)

Fig. 791.

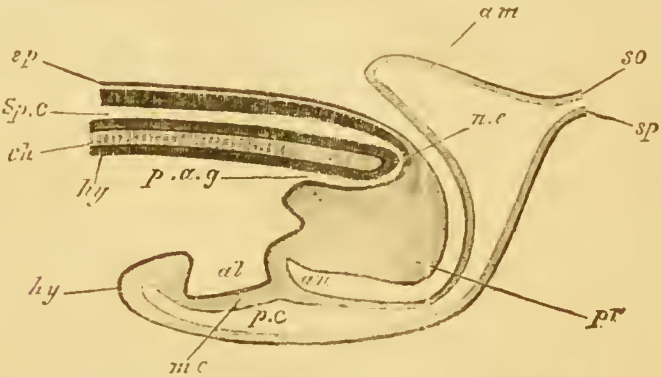


Fig. 791.—DIAGRAMMATIC LONGITUDINAL SECTION OF THE HINDER PART OF AN EMBRYO CHICK AT THE TIME OF THE FORMATION OF THE ALLANTOIS (from Balfour).

ep, epiblast; *Sp.c*, spinal canal; *ch*, notochord; *n.c*, neurenteric canal; *hy*, hypoblast; *p.a.g*, postanal gut; *pr*, remains of primitive streak folded in on the ventral side; *al*, allantois; *me*, mesoblast; *an*, place of future anus; *pc*, perivisceral cavity; *am*, amnion; *so*, body-wall; *sp*, visceral wall.

THE LIVER AND PANCREAS.

The Liver.—The liver is one of the earliest formed abdominal organs. It consists at first, according to most observers, of a bifid mass of cells in connection with the lower surface of the duodenal portion of the alimentary canal. A hollow cavity soon appears within the mass, which is the commencement of the main excretory duct (ductus choledochus communis). This cavity is lined by hypoblastic epithelium; and, according to the commonly received view, is produced as a diverticulum of the hypoblast of the intestine. Through the liver mass, but at first unconnected with its substance, there passes the main stem of the veins from the umbilical vesicle and allantois (umbilical vein or meatus venosus).

In the rudimentary mass composing the liver there are soon observed a number of solid cylinders of formative cells which branch out from the hypoblast into the mesoblast, and with this peculiarity belonging to the structure of the liver as compared with other glands, that, as these unite together by their ends and also laterally, they come at last to form a network of solid cords with which the hypoblastic diverticula are connected. In the meantime blood-vessels are developed in the mesoblast lying between the cylinders, which vessels become united as branches with the umbilical vein passing through the liver. Hollow processes also extend themselves from the hypoblastic diverticula and stretch into the solid cylinders of the hepatic parenchyma; but the greater part of this remains solid for a time, consisting of reticulated strings of cells between which there is nothing but blood-vessels.

According to Foster and Balfour, following Remak and the earlier observers, the cellular elements of the gland are stated to derive their origin from the hypoblast, and the mesoblast is mainly converted into blood-vessels and the fibrous tissue of the ducts.

The gall-bladder is formed by extension from the wall of the main duct.

The blood-vessels formed in the liver become branches of the main vein which passes through the cellular mass. These are distinguishable as an anterior and posterior set, the arrangement of which is such that the blood flows from stem to branches in the anterior, and from branches to stem in the posterior. Thus the distinction is established between portal and hepatic veins (see the Development of the Veins).

The solid cylinders of the blastema represent the hepatic lobular tissue, where the ducts are reticulated; the hollow processes the larger hepatic ducts, which do not communicate with one another. The origin of the finest ducts is not known; perhaps each cellular cylinder may be looked upon as a collection of hepatic cells, in the centre of which is the minute duct, according to the view now taken of the structure of the adult liver (Foster and Balfour).

The gall-bladder is at first tubular, and then assumes a pyriform shape. It first appears in the second month. The alveoli in its interior appear about the sixth month. At the seventh month it first contains bile. In the fœtus its direction is more horizontal than in the adult.

The following are the principal peculiarities in the liver of the human fœtus:—

Size.—At the sixth or seventh week, the liver is so large that it is said to constitute one-half of the weight of the whole body. This proportion gradually decreases as development advances, until at the full period the relative weight of the fœtal liver to that of the body is as 1 to 18.

In early fœtal life, the right and left lobes of the liver are of nearly equal size. Later, the right preponderates, but not to such an extent as after birth. Immediately before birth the relative weight of the left lobe to the right is nearly as 1 to 1·6.

Position.—In consequence of the nearly equal size of the two lobes, the position of the fœtal liver in the abdomen is more symmetrical than in the adult. In the very young fœtus it extends over nearly the whole of the abdominal cavity; at the full period it still descends an inch and a half below the margin of the thorax, overlaps the spleen on the left side, and reaches nearly down to the crest of the ilium on the right.

Form, Colour, &c.—The fœtal liver is considerably thicker in proportion from above downwards than that of the adult. It is generally of a darker hue. Its consistence and specific gravity are both less than in the adult.

During fœtal life, the umbilical vein runs from the umbilicus along the free margin of the suspensory ligament towards the anterior border and under surface of the liver, beneath which it is lodged in the umbilical fissure, and proceeds as far as the transverse fissure. Here it divides into two branches; one of these, the *ductus venosus*, continues onward in the same direction, and joins the vena cava. The other, which is the larger branch (the trunk of the umbilical vein), turns to the right along the transverse or portal fissure, and ends in the vena portæ, which, proceeding from the veins of the digestive organs, is in the fœtus comparatively of small dimensions. The umbilical vein, as it lies in the umbilical fissure, and before it joins the vena portæ, gives off large lateral branches, which pass directly into the right and left lobes of the liver. It also sends a few smaller branches to the square lobe and to the lobe of Spigelius.

Fig. 792.

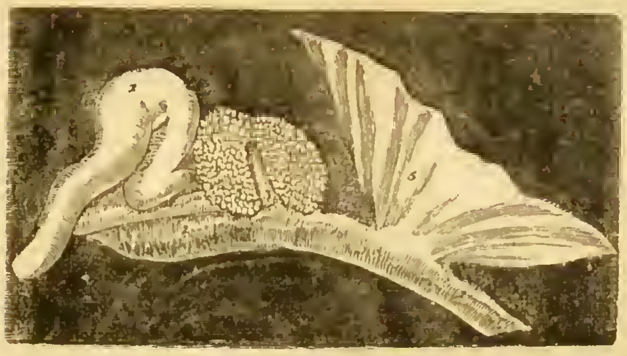


Fig. 792. — Early condition of the liver in the chick on the third day of incubation (from J. Müller). $\frac{10}{1}$.

1, the heart as a simple curved tube; 2, 2, the intestinal tube; 3, conical protrusion of the coat of the commencing intestine, on which the blastema of the liver (4) is formed; 5, portion of the layers of the germinal membrane, passing into the yolk-sac.

After birth the umbilical vein becomes obliterated from the umbilicus up to the point of its giving off branches to the liver. The ductus venosus is also obliterated, but the veins which were given as branches from the umbilical vein to the liver remain in communication with and appear as branches of the left division of the portal vein.

The Pancreas.—This organ takes its origin in a mass of mesoblastic tissue, which thickens the wall of the duodenum close to the place where the rudiment of the liver is first seen, but placed more to the left side. This mass may be seen on the fourth day in the chick. There is, however, also a diverticulum from the primary wall of the intestine or hypoblast. Some doubt prevails, as in regard to the liver, with respect to the exact share of the hypoblastic and mesoblastic elements in the formation of the glandular cells. The main duct and its branches undoubtedly owe their origin to diverticula proceeding from the intestinal hypoblast, and the epithelial lining of the ducts is certainly derived from that source. By those who, adopting the most probable view, consider that the glandular cells also arise from the hypoblast, solid processes of that layer are described as stretching into the mass of mesoblast. Into these the diverticular cavities subsequently extend in more than one main division. The blood-vessels and the connective tissue of the gland are undoubtedly due to the mesoblastic elements, and these are very soon combined with the parts proceeding from hypoblast.

Fig. 793.

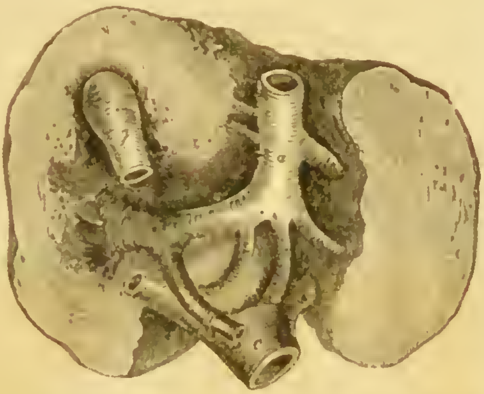


Fig. 793.—Under surface of the fœtal liver, with its great blood-vessels, at the full period.

a, the umbilical vein, lying in the umbilical fissure, and turning to the right side, at the transverse fissure (o), to join the vena portæ (p): the branch marked d, named the ductus venosus, continues straight on to join the vena cava inferior (c): some branches of the umbilical vein pass from a into the substance of the liver: g, the gall-bladder.

The development of the spleen is described along with that of the lymphatic system at p. 877.

THE LUNGS, TRACHEA, AND LARYNX, &c.

The very first appearance of the pulmonary organs in birds and mammals consists of a single median diverticulum from the ventral wall of the œsophagus immediately behind the fourth visceral cleft. The lower extremity of this protrusion soon becomes dilated towards the two sides, while its root communicating with the gullet remains single. These primitive protrusions or tubercles are visible in the chick on the third day of incubation, and in the embryoes of mammalia and of man at a corresponding stage of advancement. Their internal cavities communicate with the œsophagus, and are lined by a prolongation of the hypoblast.

The diverticulum of hypoblast is surrounded by a mass of mesoblastic cells, so that the pulmonary parenchyma, like that of the glands, owes its origin to both hypoblastic and mesoblastic elements. The substance of the mesoblast, thickening round the primary diverticula, becomes penetrated by secondary diverticula formed from the hypoblastic processes; these are succeeded by tertiary branches which develop the

Fig. 794.

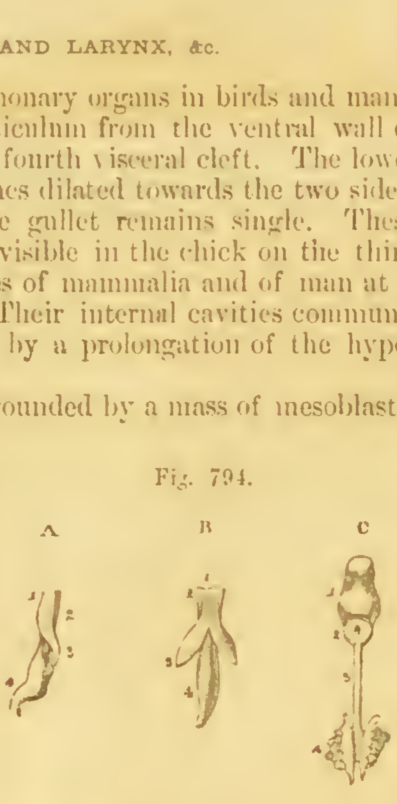


Fig. 794.—Sketch illustrating the development of the respiratory organs (from Rathke).

A, œsophagus of a chick, on the fourth day of incubation, with the rudimentary lung of the left side, seen laterally; 1, the front, and 2, the back of the œsophagus; 3, rudimentary lung protruding from that tube; 4, stomach. B, the same seen in front, so as to show both lungs. C, tongue and respiratory organs of embryo of the horse; 1, tongue; 2, larynx; 3, trachea; 4, lungs seen from behind.

bronchia, and ultimately have the air-cells formed as their terminations. The formative process consists essentially in the budding of hypoblastic into mesoblastic substance; the hypoblast furnishing the lining epithelium of the tubes, and the mesoblast the other tissues, such as muscular fibres, cartilage, blood-vessels, elastic tissue, &c.

Fig. 795.

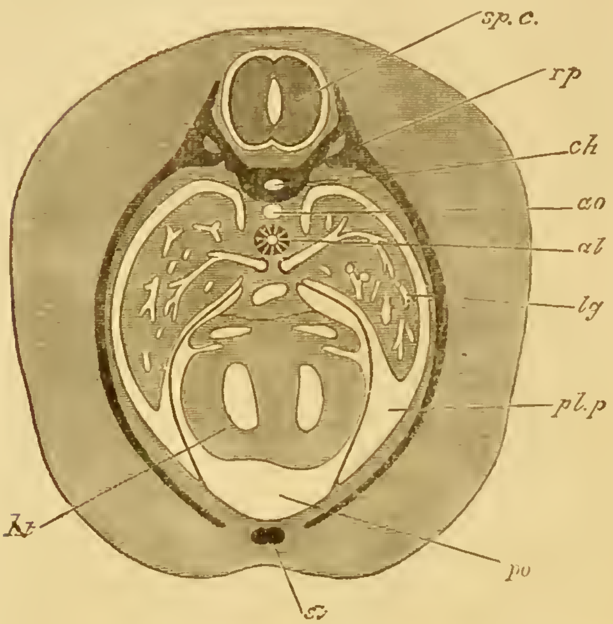


Fig. 795.—Section through an advanced embryo of a rabbit to show the relations of the pericardial and pleural cavities (from Balfour).

ht, heart; *po*, pericardial cavity; *pl.p*, pleural cavity; *lg*, lung; *al*, alimentary tract; *ao*, dorsal aorta: *ch*, notochord; *rp*, rib; *st*, sternum; *sp.c*, spinal cord.

The division into larger lobes externally, three in the right and two in the left lung, may be seen at a very early period in the human fœtus. As the bronchial subdivision extends within the lungs, a tubercular or coarsely granular appearance is seen over the outer surface, as observed by Kölliker, in the human fœtus in the latter half of the second month. This is produced by the primitive air-cells placed at the extremities of ramified tubes, which occupy the whole of the interior of the organ: the ramification of the bronchial twigs and multiplication of air-cells go on increasing, and this to such an extent that the air-cells in the fifth month are only half the size of those which are found in the fourth month.

In birds the principal air-sacs, three in number, are formed in direct connection with the lung in the course of its early development, and the rudiments of these sacs may be seen at an early period, as bulging constituent parts of the rudimentary lungs.

Pleuræ.—Each lung receives a covering externally from the lining membrane of the common pleuro-peritoneal cavity of its own side. This is at first only on the outer side; but, as the lungs enlarge, a fissure separates their solid substance from the outer wall of the œsophagus, and the pleura is carried round the lung-mass so as to encircle the gradually narrowing root of each lung. The two pleuræ remain separated by the mediastinum and heart, round which they have extended.

Pulmonary Vessels.—The blood-vessels of the lungs, which arise in the mesoblastic tissue, seem to be of comparatively late formation, penetrating into the pulmonary tissue only on the twelfth day in the chick. In mammals the blood-vessels are formed in the same manner in the pulmonary mesoblast. In birds, as before mentioned, the pulmonary arteries proceed one from each of the fifth arterial aortic arches, but in mammals both right and left pulmonary arteries are connected with the fifth arch of the left side. The manner in which they become connected with the vessels formed in the lung-substance, and in which a union is established between the pulmonary veins and the left auricle, has not yet been ascertained.

Thyroid Body.—This seems to be the proper place at which a reference may be made to the two organs of doubtful nature—viz., the thyroid and thymus bodies—which have generally been ranked with the vascular glands, but which from their development appear to have also some close connection with the anterior part of the alimentary canal.

The thyroid gland takes its origin both in birds and mammals (W. Muller (No. 263), Kölliker (No. 28, i., p. 869), by a diverticulum from the ventral wall of the pharynx opposite to the place where the aortic bulb divides into the anterior visceral arches, and it is conjectured that it may be homologous with the endostyle or ventral diverticulum of the pharynx in the lampreys. It consists at first of a mass of hypoblast which in birds is hollow, but in mammals is solid; and in both classes large glandular cells are soon developed, which Kölliker represents in the rabbit as taking the form of reticulated cellular cords. The hypoblastic part soon acquires mesoblastic elements, in which blood-vessels and fibrous tissue are rapidly developed, and the thyroid body becomes highly vascular.

In birds the primary diverticular mass loses its connection with the pharynx at an early period, divides into two separate parts, and is carried back in the neck along with the elongation of that part, so as to form two very distinct compact spheroidal bodies situated near the division of the trachea.

In mammals the thyroid mass becomes somewhat bilobed, the larger lateral parts remaining united by the isthmus across the trachea.

In man the first origin of the thyroid body has not yet been observed. In the second and third months the glandular cords and follicular cavities begin to appear, and these go on increasing rapidly in the following months.

The Thymus Gland.—According to Kölliker's observations in the rabbit, this body is originally of epithelial nature, and arises as a diverticulum from an anterior pair of the visceral clefts, forming a small longish thick-walled triangular sacculus with two hollow tubular cornua. It soon divides into lobes, and in these gland-cells make their appearance, blood-vessels and other tissues being added from mesoblastic sources.

The view taken by Kölliker as to the origin of the thymus has been confirmed by the observations of Stieda in the pig and sheep, in which he found the thymus to arise as a paired outgrowth from the remnants of two visceral clefts; and he and Wölfler attribute a similar mode of origin to the thyroid body. (273 and 274.)

V. DEVELOPMENT OF THE URINARY AND GENERATIVE ORGANS.

1. GENERAL VIEW.

The development of the permanent urinary and generative organs has long been known to be intimately associated with that of the embryonic glandular organs named the primordial kidneys, or after their discoverer, C. F. Wolff, the Wolffian Bodies. This association was first ascertained by H. Rathke, Oken, and Joh. Müller more than fifty years ago, and the fuller knowledge of its nature has been illustrated by numerous embryologists in investigations of more recent date (Bornhaupt, Kobelt, Kölliker, Waldeyer, Semper, Balfour and others).

Fig. 796.

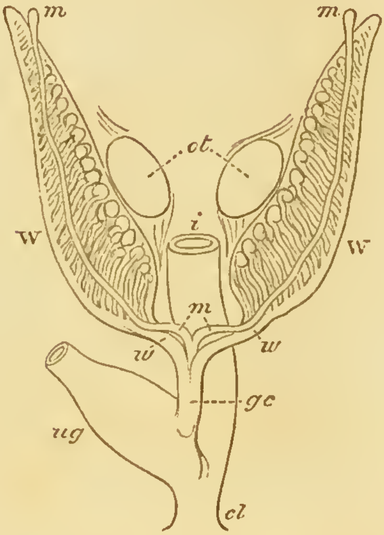


Fig. 796.—DIAGRAMMATIC OUTLINE OF THE WOLFFIAN BODIES IN THEIR RELATIONS TO THE RUDIMENTS OF THE REPRODUCTIVE ORGANS. (A. T.)

ot, seat of origin of the ovaries or testes ; W, Wolffian bodies ; *w. w*, Wolffian ducts ; *mm*, Müllerian ducts ; *gc*, genital cord ; *ug*, sinus urogenitalis ; *i*, intestine ; *cl*, cloaca.

Wolffian Bodies and Segmental Organs.—According to the two last named observers, the Wolffian bodies are the representatives in a certain stage of their development of a set of tubular glands or excretory organs existing in all vertebrates and in a certain number of invertebrate animals, especially annelida, to which the general name of *segmental organs* may be given, from their relations to the metameric somites of the body.

It was first shown by Rathke in 1826 that the Wolffian bodies of all vertebrates consist of glandular tubes with which are combined vascular glomeruli of the same general nature as those of the adult kidney ; and recent researches have further shown that an essential structural character of the bodies in question, in the great majority of animals in which they are found, is the existence at an early stage of development of an opening on the one hand of a certain number of their tubes into the body cavity of the embryo, and on the other, of one or more of their main ducts into the cloaca or hinder part of the alimentary canal.

In the amniota, that is in reptiles, birds and mammals, while the greater part of the segmental organs known as the Wolffian bodies becomes atrophied and disappears in early fœtal life, a further development of organs of a similar structure gives rise to the permanent kidneys, and parts of the embryonic segmental organs with their ducts contribute to the formation of the adult male and female generative organs.

Distinction of Pronephros, Mesonephros, and Metanephros.—The simultaneous researches of Semper and Balfour in elasmobranch fishes have led them to distinguish three typical or fundamental parts of the segmental organs, all of which agree more or less, 1st, in their characteristic renal or combined tubular and glomerular structure, and 2nd, in their opening on the one hand anteriorly and internally into the abdominal cavity, and on the other posteriorly into the cloaca.

These bodies may be regarded as three serial divisions of an entire segmental apparatus extending on each side of the body of a vertebrate embryo from the head or region of the heart to the cloaca in the hinder part of the body. The middle division, which in the embryonic condition is the largest, is the Wolffian body before referred to: the anterior, much smaller and less constant among animals, is the head-kidney of Balfour and Sedgwick; and the posterior one, later of being formed than the other two, corresponds to the permanent kidney of the amniota. To these several divisions of the segmental apparatus Ray Lankester has given the appropriate designations of Pronephros, Mesonephros and Metanephros.

Wolffian and Müllerian Ducts.—Each of these three divisions of the segmental organs possesses an excretory duct—viz., the Müllerian duct belonging to the pronephros or head-kidney, the Wolffian duct to the mesonephros or Wolffian body, and the ureter to the metanephros or permanent kidney of the amniota.

Fig. 797.

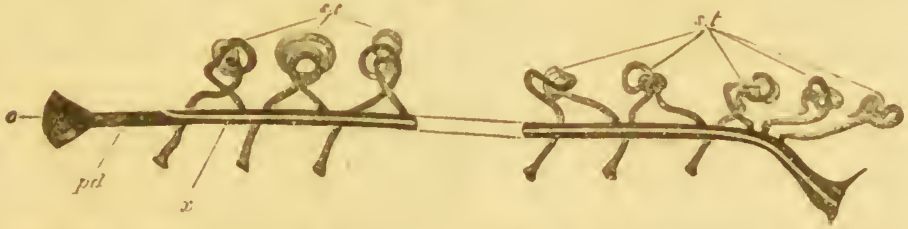


Fig. 797.—Diagram of the primitive condition of the kidney in an elasmobranch embryo (from Balfour).

pd, segmental duct; opening at *o*, into the body cavity and at its other extremity into the cloaca; *x*, line of separation between the Wolffian duct above and the Müllerian duct below; *st*, segmental tubes, opening at one end into the body cavity and at the other into the segmental duct.

The general nature and relations of these segmental organs, considered as embryonic structures, and as the foundation and precursors of the permanent urinary and internal generative organs, will be best explained by following Balfour's very clear statement of the principal steps of their development in elasmobranch fishes.

Origin and Formation of the Segmental Organs.—The segmental organs of the vertebrates originate in a long shaped mass of formative cells, which, at a period corresponding to the latter half of the second day of incubation in the chick, is seen to be separated from the mesoblast in a recess between its mesial or protovertebral and its lateral columns, and which has hence received the name of *intermediate cell-mass.* The separation of this cell-mass as a distinct cord or column begins in the region of the fifth somite or protovertebra in the chick, and extending from thence backwards to near the hinder part of the primitive gut, it finally reaches the cloaca with which it is connected. It is at first solid, but soon acquires a lumen within, and thus forms a tube, the greater part of which corresponds with that which was earlier known as the Wolffian duct, but which in its entirety, according to the more recent views before quoted, may be named the *segmental duct.* This column with its duct at the same time changes its position by sinking down in a ventral direction, so that it comes to project in the body-cavity, and soon, by a rapid increase of formative substance round it, the whole forms a longitudinal column on each side of the mesentery between the parietal and visceral divisions of the mesoblast.

Segmental Tubes.—Within this columnar mass a series of tubular offsets are early developed (Wolffian tubes) which have the general form of short transverse cæca directed inwards and connected externally with the main segmental duct. These tubes in the lower vertebrates, and in reptiles among the amniota, correspond closely in number with the vertebral or muscular somites in the region which they occupy; but in birds and mammals, though at first nearly so corresponding, they come later to be more numerous by the addition both of original and of secondary tubes. These may be named the *segmental tubes*. In its primary form, therefore, the segmental organ might be described as consisting of a main duct or canal with a number of cæcal tubuli branching from it or leading into it laterally.

Fig. 798.

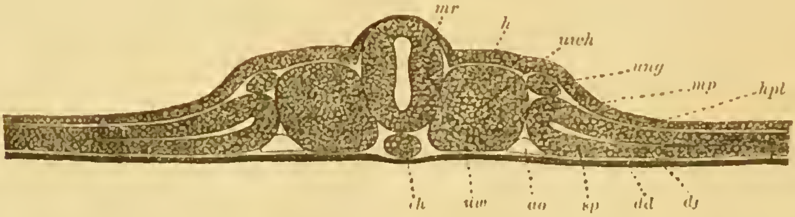


Fig. 798.—Transverse section through the embryo of the chick and blastoderm on the second day (from Kölliker).

d d, hypoblast; *ch*, chorda dorsalis; *u w*, primordial vertebræ; *m r*, medullary plates; *h*, corneous layer or epiblast; *u w h*, cavity of the primordial vertebral mass; *m p*, mesoblast dividing at *s p* into *h p l*, body wall, and *d f*, visceral wall; *u n g*, Wolffian duct, beginning in the intermediate cell-mass. (See also figs. 690 and 692.)

Fig. 799.

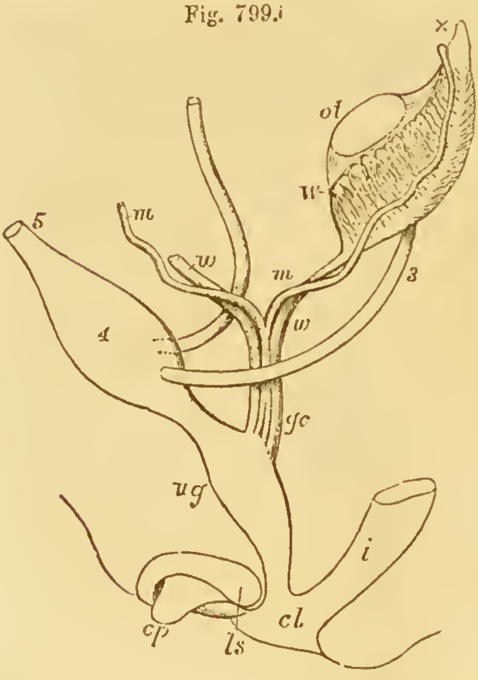


Fig. 799. — Diagram of the primitive uro-genital organs in the embryo previous to sexual distinction.

The hinder parts are shown chiefly in profile, but the Müllerian and Wolffian ducts are seen from the front, entire upon the left and cut short upon the right side. 3, ureter; 4, urinary bladder; 5, urachus; *ot*, the genital ridge from which ovary or testicle is afterwards formed; W, left Wolffian body; ×, anterior part from which the coni vasculosi are afterwards developed; *w.w*, right and left Wolffian ducts; *m.m*, right and left Müllerian ducts uniting together and with the Wolffian ducts in *gc*, the genital cord; *ug*, sinus urogenitalis; *i*, lower part of the intestine; *cl*, cloaca; *cp*, elevation which becomes clitoris or penis; *ls*, fold of integument from which the labia majora or scrotum are formed.

Very soon, however, a great modification and complication in the structure and relations of this organ takes place in three ways which may be shortly stated as follows :—1st, by the formation of openings from the inner ends of some of the segmental tubes, and later of the segmental duct itself into the peritoneal or body cavity at its upper or dorsal part ; 2nd, by the increased growth and convolution of the tubules, especially of the mesonephros, and by the development of vascular glomeruli in connection with them : and 3rd, by the formation of a new collateral duct in the vicinity of the original segmental duct, and certain changes in the association of the segmental tubes with the two ducts which thus come to take the place of the original segmental duct. These latter changes are of such a nature that the greater number of the glandular tubules forming the mesonephros remain connected with that part of the segmental duct which becomes the Wolffian duct, and are thus brought to a common opening in the cloaca ; while (as ascertained in some vertebrates, though not in all) some of the anterior tubules are left in connection with the separate or newly-formed duct,

Fig. 800.

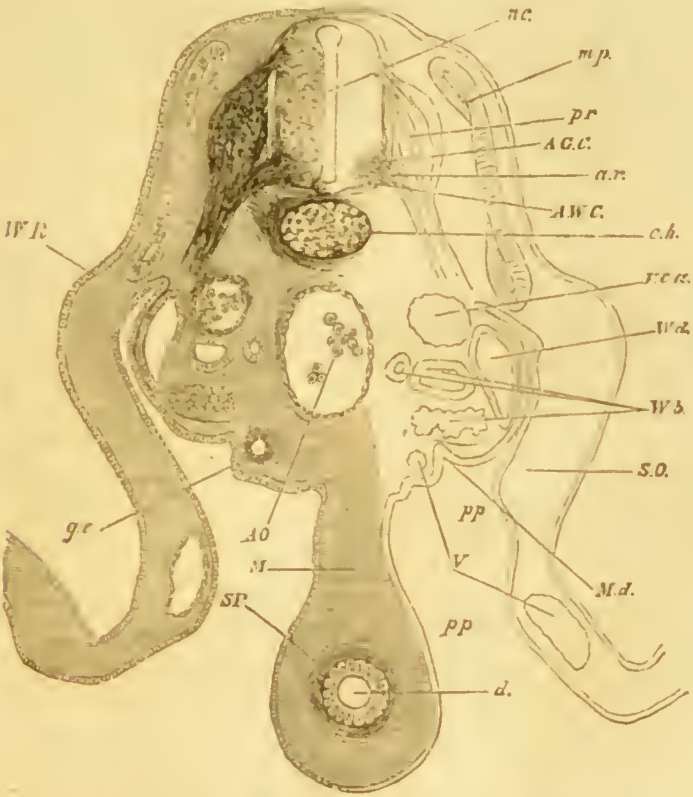


Fig. 800.—SECTION THROUGH THE LUMBAR REGION OF AN EMBRYO CHICK OF FOUR DAYS (from Foster and Balfour).

nc, neural canal ; *pr*, posterior root and ganglion of a spinal nerve ; *ar*, anterior root ; *mp*, muscle-plate ; *ch*, notochord ; *WR*, Wolffian ridge ; *AO*, aorta ; *Vc a*, cardinal vein ; *Wd*, Wolffian duct ; *Wb*, Wolffian body with glomeruli ; *gr*, germinal epithelium ; *Md*, depression forming the commencement of the Müllerian duct ; *d*, alimentary canal ; *M*, mesentery ; *SO*, body-wall ; *SP*, visceral wall ; *V*, blood-vessels ; *pp*, pleuro-peritoneal space.

which, having been originally discovered by Joh. Müller in 1830, has since been named the Müllerian duct.

The ureter may be looked upon as an offset from the hinder part of the Wolffian duct, and the metanephros of the elasmobranchs consists of a set of segmental tubes developed in connection with this duct, possessing the same glandular and glomerular structure as the mesonephros, and occupying a situation which is on the dorsal aspect of the Wolffian duct and near its hinder part. The characteristic feature in the development of the urino-genital system in the amniota is according to Balfour the formation of a metanephros or permanent kidney, and the complete or partial disappearance of the other two parts of the segmental organs—viz., the pronephros and mesonephros.

The Müllerian and Wolffian ducts stand in a different relation to the productive organ in the two sexes. In the female the Müllerian duct becomes developed into the whole length of the genital passages, and the Wolffian duct almost entirely disappears. In the male, on the other hand, the Wolffian duct becomes converted into the excretory duct (vas deferens) of the testicle ; while the Müllerian duct undergoes atrophy and has no permanent existence.

Fig. 801.

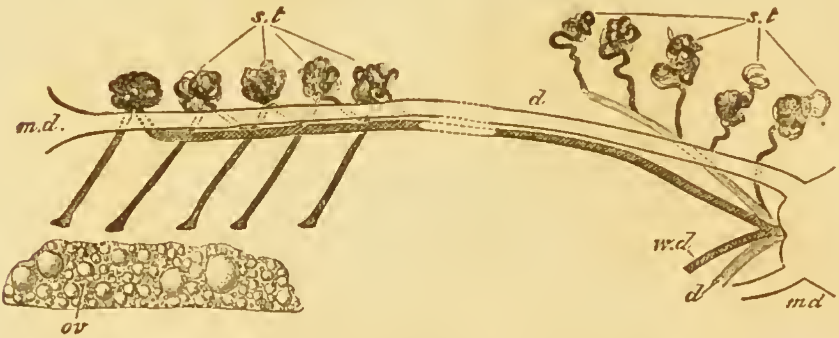


Fig. 801.—Diagram of the arrangement of the urino-genital organs in an adult female elasmobranch (from Balfour).

m.d., Müllerian duct ; *w.d*, Wolffian duct ; *s.t*, segmental tubes ; five of them are represented with openings into the body cavity, and five posteriorly correspond to the metanephros ; *ov*, the ovary ; *d*, ureter.

In connection with the conducting passages of both sexes there are found in later life vestiges of those of the embryonic structures which are not employed in the production of the permanent generative organs, and these vestiges are of considerable interest in their bearing upon the history of the changes by which the permanent organs are formed.

Genital Ridge and Germ-Epithelium.—In all the Vertebrates the productive gland of the generative system, ovary or testicle, takes its origin from formative blastema situated on the mesial side of each Wolffian body or mesonephros at an early period of embryonic life, and there is in the commencement a close connection between the origin of the first elements of the sexual products, ova or spermatic cells, and a portion of the epithelium which lines the body cavity in that region. Here an elevation of the blastema and thickened epithelium marks the presence of the *genital ridge*, and the name of *germ-epithelium* is given to the more developed portion of the epithelium from which the generative elements are derived.

In the lower vertebrates the anterior part of the Müllerian duct is connected with the pronephros, and the opening by which this duct communicates at its anterior extremity is probably one of the peritoneal apertures of that portion of the segmental organs. Among the amniota the pronephros or head-kidney is as yet only known in birds by the researches of Sedgwick and Balfour; but, according to the views of the latter, it seems probable that the anterior part of Müller's duct is, in reptiles and mammals as well as in birds, homologous with the duct of the pronephros. Although, therefore, the tubular part of the pronephros is not developed in these animals, there is reason to hold that the type of development of their urogenital passages is, in the main, the same as in birds and the lower vertebrates.

The relation of the origin of the productive sexual organs to the mesonephros, though not yet fully ascertained, is known to be closer in the male than in the female sex. Thus there is good reason to believe that, while in both sexes, as already stated, the productive elements are derived from the germinal cells of the genital ridge, there are differences in the further development of the organs containing the generative elements, as in the Graafian follicles in the one and the spermatic tubes in the other.

Fig. 802.

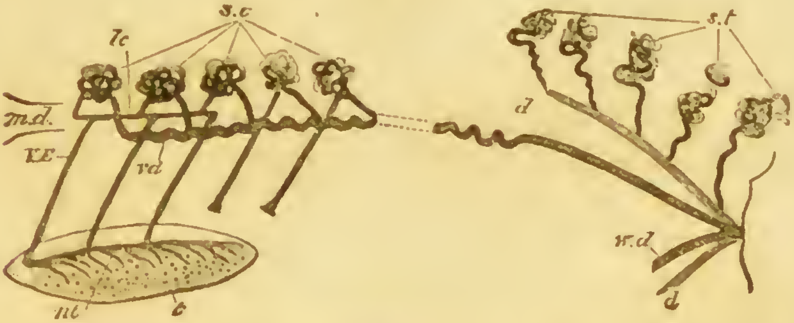


Fig. 802.—Diagram of the arrangement of the urino-genital organs in an adult male elasmobranch (from Balfour).

m.d., rudiment of Müllerian duct; *w.d*, Wolffian duct, serving at *vd* as vas deferens; *s.t*, segmental tubes, two represented with openings into the body cavity; *d*, ureter; *t*, testis; *nt*, canal at the base of the testis; V.E, vasa efferentia; *lc*, longitudinal canal of the Wolffian body.

The External Organs.—With regard to these organs, it is sufficient to remark in this place that the structural elements from which they take their origin are essentially the same in the two sexes, and that their special sexual characters in the male and female depend rather upon differences in the degree and manner of their development than upon any fundamental disparity in their nature. The nature of the process will be more fully explained hereafter.

In all mammals, with the exception of the monotremata, the distinctive development of the external organs is preceded by the separation of the cloaca internally into an anterior urogenital and posterior anal part, which when the proctodaeum is perforated open separately on the surface.

The history of the development of the parts composing the external organs in connection with the formation of their special sexual characters will be described in a later part of this chapter.

II. FURTHER DEVELOPMENT OF THE PERMANENT URINO-GENITAL ORGANS.

1. THE KIDNEYS.

The origin of the kidneys as a metanephros in connection with the hinder part of the Wolffian body on its dorsal aspect has already been adverted to. Kölliker, following Kupffer and Lieberkühn, and from his own observations, has described the first appearance of the kidney in mammals as taking place by the development of a tubular diverticulum from the Wolffian duct near its termination in the cloaca. This tube represents the earliest condition of the ureter, and it extends into a mass of mesoblastic cells corresponding or continuous with that of the Wolffian body from which the glandular part of the kidney is gradually developed. The distinction between the tubular or ureter part and that which is to become the parenchyma of the gland becoming more apparent, the latter increases greatly in volume, and rapidly encroaching on the space above the Wolffian body comes to occupy the whole of the region between it and the aorta, and even to project further forward, while other changes in the interior indicate the process of formation of the gland. In the ureter the hinder part elongates as a single tube, but the forepart becomes dilated and subdivided into cæca or wider portions which represent the commencement of the several divisions of the pelvis. These divisions are surrounded by masses of the glandular blastema, into which there pass smaller cæcal tubes which seem to sprout from the pelvic hollows of the original ureter. These tubes then become convoluted, and on their exterior small masses of cells accumulate in which the vascular glomeruli are gradually formed by the development of blood-vessels within them. These blood-vessels remain connected with the external blastema in which they arise by means of a stalk or pedicle, but the glomerulus now comes to be projected into a doubling of the uriniferous tubule in the manner which belongs to all such renal structures. There is at first no distinction between the straight and the convoluted parts of the tubular substance, but this arises later by the gathering together of the convoluted parts in rounded masses towards the exterior, and the elongation of the straighter tubes internally, while at the same time or somewhat later the latter group themselves into bundles which form the pyramids and project into the pelvic calices.

In the human fœtus of eight weeks, the Malpighian glomeruli are already apparent. In the third month the papillæ are formed, and in the fourth the recurved tubes of Henle have become apparent. At first, therefore, the kidneys seem to consist wholly of cortical substance, with only convoluted tubes, and the formation of the straight tubular substance is the result of a later change. The tubes are absolutely, as well as relatively, wider in early fœtal life than in the adult.

In the human fœtus of ten weeks the kidneys have acquired their peculiar bean-like shape with the hilus for the ureter, pelvis and vessels. They are also distinctly lobulated externally, and they retain this form up to the time of birth, and during the first year of infancy, and it is not uncommon to find the lobulated form in kidneys of a later period.

Urinary Bladder and Urachus.—The urinary bladder, as already stated in an earlier part of this description, is formed by a dilatation of the stalk of the allantois. In the human fœtus this appears as a spindle-shaped cavity at the end of the second month, the narrower part below being prolonged as the first part of the urethra into the cloaca, while the upper narrowing part extends as the urachus into the umbilical cord, and at an early period in animals is prolonged into the cavity of the allantois.

The ureters terminate in the dorsal wall of that part of the urogenital sinus which is dilated into the urinary bladder.

The urachus is usually a solid cord at a short distance from the bladder, but, according to Luschka, it not unfrequently remains hollow for some length within the umbilical cord.

The spindle shape of the bladder is retained for a long time in the human fœtus.

For the development of the Suprarenal bodies, see p. 841.

Genital Cord.—In both sexes, as was first fully shown by Tiersch (No. 287) and Leuckart (No. 287*) in 1852, the two Wolffian ducts are united by surrounding substance into one cord behind what becomes the base of the urinary bladder; but retaining internally their separate passages until they reach the sinus urogenitalis. With this cord the Müllerian ducts are incorporated posteriorly, so that at one time there are four passages through the whole of the genital cord. The Müllerian ducts next coalesce into one at some little distance from their lower ends, and this fusion progressing upwards and downwards for a considerable space, a single median cavity is produced which lies between the still separate canals of the Wolffian ducts. A large accumulation of tissue in its walls gives to the genital cord great thickness as compared with the neighbouring parts of the ducts where they emerge from its enclosure. The lower part of the united Müllerian ducts thus comes afterwards to form the foundation of the vagina and lower part of the uterus in the female, and the corresponding prostatic vesicle with its occasional vestigial accompaniments in the male, or the uterus masculinus.

Fig. 803.

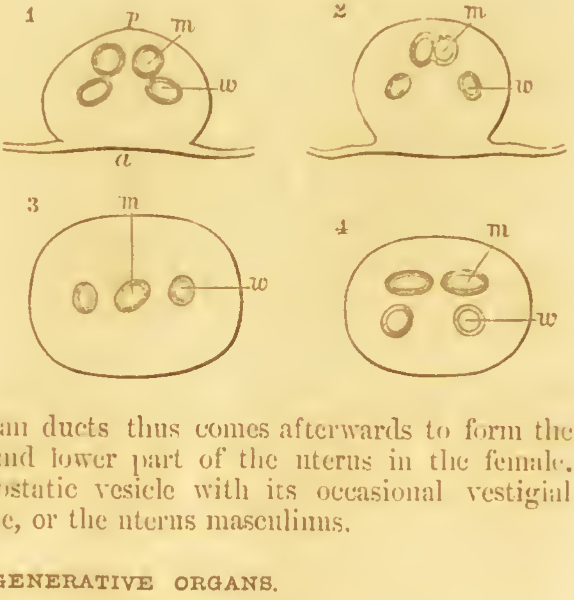


Fig. 803.—Transverse sections of the genital cord in a female calf embryo. Magnified 14 diameters (from Kölliker).

1, near the upper end; 2 and 3, near the middle; 4, at the lower end; *a*, anterior, *p*, posterior aspect; *m*, Müllerian ducts united or separate; *w*, Wolffian ducts.

II. GENERATIVE ORGANS.

In the history of the further development of the generative organs it will be convenient to consider them in the two sexes in succession under the three heads of, 1st, the reproductive glands, or strictly internal organs; 2nd, the conducting passages or intermediate organs; and 3rd, the external organs.

1. **Reproductive Glands.**—From all recent researches it appears certain, as previously stated, that the reproductive elements of the two sexes take their origin from an identical source, viz., the germ-epithelium of the genital ridge, situated on the mesial side of each Wolffian body. It appears further that in the earliest stages of both the sexes the thickening of the genital ridge by the columnar enlargement of its epithelial cells occurs nearly in like manner; and it is even further stated that, in embryoes exhibiting a tendency to be developed as males, an enlargement of some of the germ-epithelial cells into the form of primordial ova is observed of the same kind as in embryoes about to become females. But as development advances, the similarity in the condition of the genital ridge becomes less, and the germ-epithelial cells remain on the whole flatter in the male than in the female.

In the human embryo the distinction of sex begins to be perceptible in the internal organs in the seventh week, and becomes more apparent in the eighth. The reproductive gland is from the first connected with the Wolffian body, with which its blastema seems to be actually in part continuous; and it remains attached to it, or after its disappearance, to the structure which occupies its place, by a fold of the peritoneal membrane, constituting the mesorchium or mesovarium. Upper and lower bands fix the Wolffian body; the upper passing to the diaphragm may be named the diaphragmatic; the lower, running down towards the groin from the Wolffian duct, contains muscular fibres and constitutes the future gubernaculum testis and round ligament of the uterus.

Fig. 804.

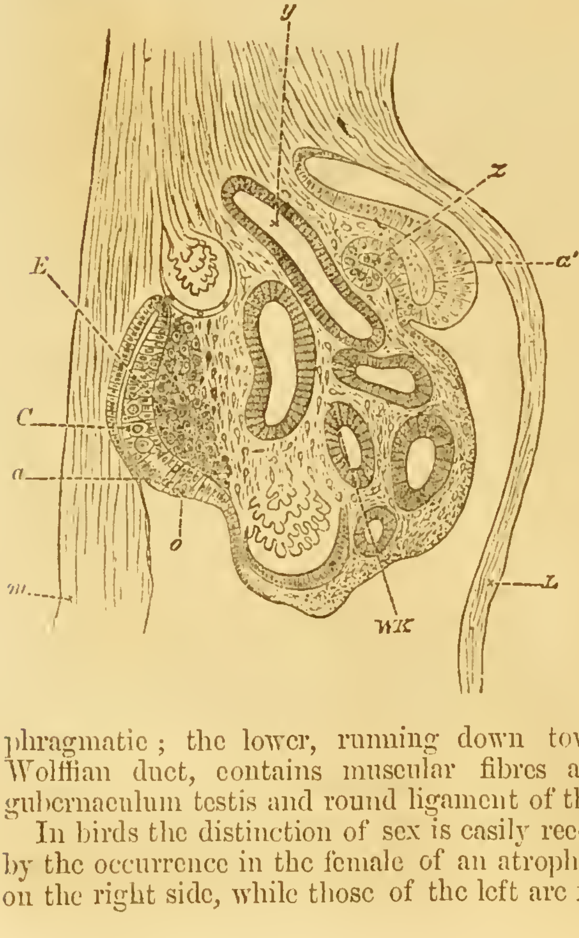


Fig. 804.—TRANSVERSE SECTION OF THE WOLFFIAN BODY OF THE CHICK DEVELOPING THE PRONEPHROS AND GENITAL GLAND ON THE FOURTH DAY (from Balfour after Waldeyer).

m, mesentery; *L*, body-wall; *a'*, portion of the epithelium from which the involution of the anterior part of the Müllerian duct *z*, is taking place; *a*, thickened germinal epithelium in which are seen primitive germinal cells, *C* and *o*; *E*, modified mesoblast which will form the stroma of the ovary; *WK*, Wolffian body; *y*, Wolffian duct.

In birds the distinction of sex is easily recognisable at an early period by the occurrence in the female of an atrophy of the ovary and passages on the right side, while those of the left are fully developed.

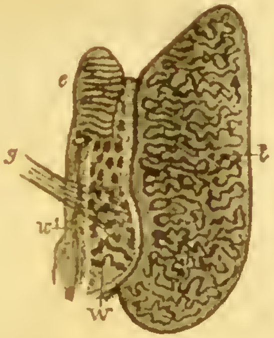
The Testicle.—In male human embryoes at the tenth week already seminal canals are visible, being at first, according to Kölliker, entirely composed of cells, but by the eleventh and twelfth weeks the tubes have become somewhat smaller, longer, and are now branched and possess a membrana propria. There is also by the end of the third month a commencement of lobular division, and the body of the testis is now covered with a condensed layer of fibrous tissue which forms the tunica albuginea. The serous covering is derived from the abdominal peritoneum.

The first origin of the glandular substance of the testis has not been observed in the human embryo, but from the observations of Egli in male embryo rabbits (No. 308) it appears that the epithelial cells, which remain smaller than in the females, soon become connected with the deeper blastema extending towards the Wolffian body, and form strings of cells running into the body of the future testis. These are the commencements of the tubuli seminiferi. Some intimate connection, however, also exists between the tubular structure of the testis and the tubes of the anterior part of the Wolffian body.

Fig. 805.—Internal genital organs of a male human embryo of 3½ inches long (from Waldeyer).

t, body of the testicle with seminal canals formed; *e*, epididymis, or upper part of Wolffian body; *w*, Wolffian body, lower part, becoming paradidymis or organ of Giraldès; *w'*, Wolffian duct, becoming vas deferens; *g*, gubernaculum.

Fig. 805.



The nature of this connection is not fully made out in birds or mammals, but, from the observations of Braun in reptiles (No. 303*), it is probable that the formation of the seminiferous tubes has some close relation with the segmental tubes of the Wolffian body, and in such a way that the germinal epithelium cells are combined with, or enclosed in these tubes, which extend into the body of the testis, and thus come to contain the rudiments of the spermatic cells. (For the development of the spermatozoa from the spermatic cells, see p. 698 of this volume.)

To the probable union between the tubular structure of the testis (rete testis, vasa recta, &c.) with the vas deferens, through the coni vasculosi, by the persistence of some of the tubes in the anterior part of the Wolffian body, reference will be made under tho description of the development of the genital passages.

The general result of recent researches appears to be that the elements of the spermatozoa, as formed in the spermatic cells, are derived from the germinal epithelium, while the secreting tubes, which contain the cells, owe their origin to a development of formative mesoblast situated between the germ-epithelium and the Wolffian body, and probably also to the direct extension of some of the segmental tubes from the Wolffian bodies.

The Ovary.—Considered as a glandular organ the ovary differs from the testicle and other glands by the absence of special excretory ducts, and by the separation of its conducting passages from the glandular or productive part of its structure. Like the testicle it begins to manifest its peculiar characteristics by the seventh or eighth week, when the germ-epithelium has attained considerable thickness, and forms a decided prominence on the mesial side of the Wolffian body. The farther development of the glandular part of the organ consists mainly in the formation of ovigerms and ova, and the enclosure of these in Graafian follicles by a peculiar combination or intermixture of the germinal cells from the surface with the deeper blastema which forms the stroma of the organ.

Fig. 806.

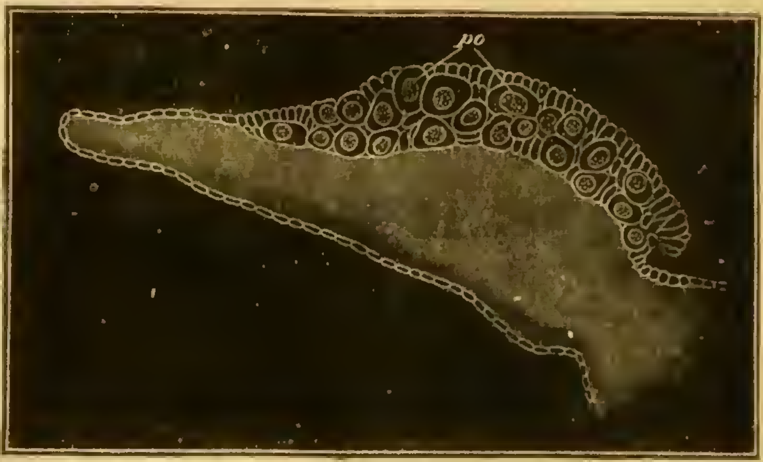


Fig. 806.—Transverse section through the ovary of an embryo shark, showing the germ-epithelium passing into primitive ova (from Balfour).

At *po*, the prismatic germ-epithelium and two primitive ova of which one is still on the surface, the other has sunk below the epithelium; elsewhere the lightly-shaded part of the figure shows the ovarian stroma or lymphatic tissue and the covering of ordinary epithelium.

Primordial Ova.—From the researches of Waldeyer (No. 58) and of many others there cannot now be any doubt that the primitive ova are derived from some of the cells of the germ-epithelium which undergo enlargement and subsequently become enclosed in Graafian follicles. But doubts have existed as to the exact manner in which this enclosure takes place, and more especially as to the source of the cellular lining of the follicle which is allied to epithelium and gives rise to the so-called granular membrane of later periods. According to the view first advocated by Waldeyer, the cells

Fig. 807.

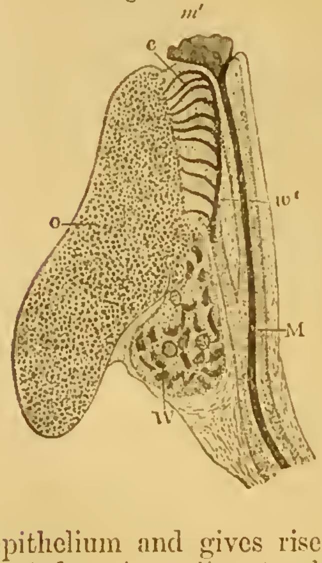


Fig. 807.—Internal organs of a female human fœtus of $3\frac{1}{2}$ inches long, or about 14 weeks. Magnified (from Waldeyer).

o, the ovary full of primordial ova; *c*, tubes of the upper part of the Wolffian body forming the epoophoron (parovarium of Kobelt); W, the lower part of the Wolffian body forming the paroophoron of His and Waldeyer; *w'*, the Wolffian duct; M, the Müllerian duct; *m'*, its upper fimbriated opening.

which form this epithelial and granular-cell lining of the follicle proceed originally from the germ-epithelium along with the primitive ova. By Foulis, on the other hand, the origin of these cells has been attributed to an enclosure and differentiation of the cells of the ovarian stroma, while Kölliker's observations have led him to adopt the view that they proceed from the cellular contents of tubes which are connected with the Wolffian body, and remain for a time as vestiges in the base of the ovary (paroophoron ?). But the observations of Ludwig (No. 59) and Balfour (No. 62) seem to show very decidedly that in the lower vertebrates the epithelial lining of the primitive follicle is the direct product of cells which, like the ova themselves, proceed from the germ-epithelium. And though it must be admitted that in the human embryo there are appearances favourable to the view taken by Foulis, the writer of this is induced from his own observations in the human ovary and that of several mammals now to give a preference to the opinion of Waldeyer.

Fig. 808.

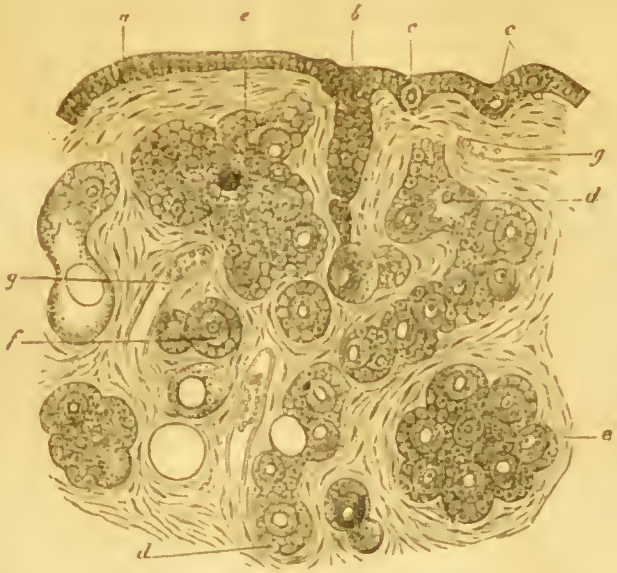


Fig. 808.—Section of the ovary of a newly-born child. Highly magnified (Waldeyer).

a, Ovarian or germinal epithelium ; *b*, formation of an ovarian tube ; *c*, *c*, primordial ova lying in the germ-epithelium : *d*, *d*, longer tube becoming constricted so as to form nests of cells ; *e*, *e*, larger nests ; *f*, distinctly formed follicle with ovum and epithelium ; *g*, *g*, blood-vessels.

In the earliest stages of ovarian development, and for a considerable time afterwards, the germinal cells of the genital ridge undergo a remarkable multiplication, and many of them while still close to the surface, become much larger than the rest, and assume the appearance of primordial ova ; the nucleus expanding into the germinal vesicle, with a distinct nucleolus (or macula) formed within it, and the external protoplasm increasing greatly to form the vitellus or yolk, but, at first, without any enclosing membrane.

As these ovigerms increase in number and size they retire from the surface of the germinal ridge or ovary, and, collecting into groups, they sink into the blastema which lies below the epithelial covering.

At the same time a great increase and extension outwards of the deeper blastema occurs, and the lymphatic cells (Balfour) of which it consists, present more and more the appearance of connective or fibro-nuclear tissue.

Ovarian Tubes and Nests.—Ere long the groups of ovigerms become enclosed in prolongations of the stroma, which in some animals present a marked tubular form, as described first by Valentin (No. 281), and afterwards more fully by Pflüger (No. 55), and in other instances assume the spherical or grape-like form, so as to deserve rather the name of *nests* which has been applied to them.

Fig. 809.

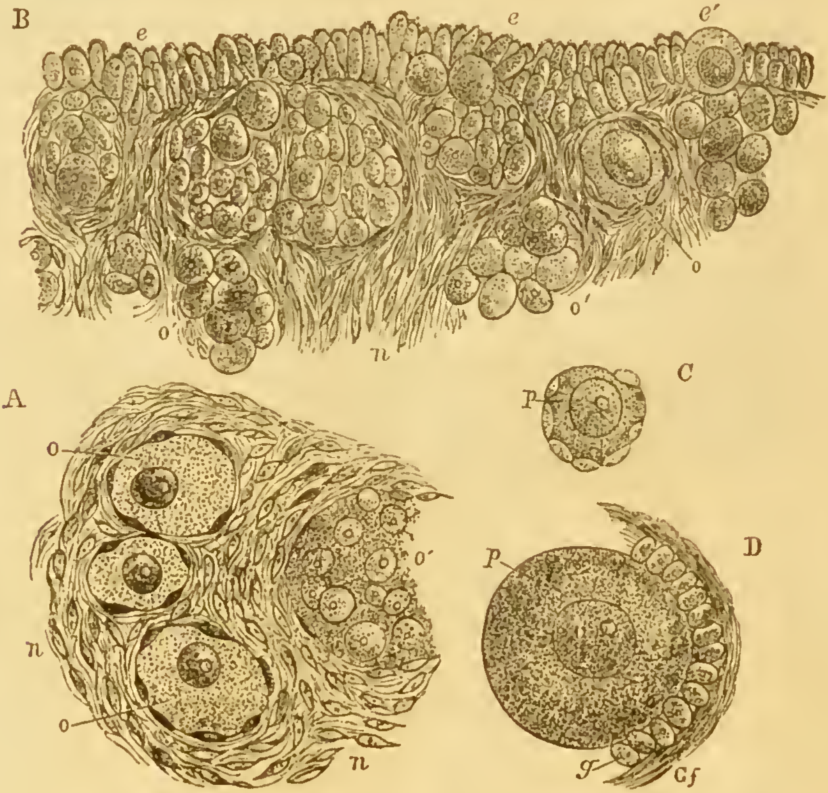


Fig. 809.—Views of the formation of ova and Graafian follicles in the ovary (from Foulis).

A, small portion of the ovary of a human fœtus of 3½ months, showing primordial ova embedded in the stroma; *o*, larger primordial ova; *o′*, cluster of earlier ova; *n*, fusiform corpuscles of the stroma. B, portion of the ovary near the surface in a human fœtus of 7½ months, showing the manner of inclusion of the germ-epithelium corpuscles in groups in the ovarian stroma; *e*, germ epithelium; *e′*, one of the cells enlarging into a primordial ovum before sinking into the stroma; *o*, a larger cell imbedded, becoming an ovum; *o′*, groups of ovigerms or germ cells which have been surrounded by the stroma. C, young ovum from the same ovary, isolated; *p*, yolk protoplasm. D, ovum more advanced, enclosed in condensed stroma, which begins to form a Graafian follicle; *p*, yolk protoplasm; *v*, germinal vesicle with macula; *g*, the enclosed corpuscles now converted into the granular cells; *Gf*, condensed stroma forming the wall of the Graafian follicle.

In these tubes and nests the enlarged cells derived from the epithelium, or ovigerms, are at first of nearly uniform size and appearance, but very soon some of them undergo a greater enlargement, while the others diminish in size, and lose the spherical form. It is not improbable that many of these last may wholly disappear, having served, according to Balfour's view (No. 62), as pabulum, or food, to those which continue to grow. The result of the whole is, however, that one, or it may be more, of the cells undergo increased development, and acquire more and more distinctly the characters of ova by the enlargement of the yolk protoplasm and germinal vesicle, while those of the others which survive alter their shape, becoming flattened nucleated cells, and arrange themselves as a more or less complete single layer of epithelium lining the cavity of ovarian stroma in which the primordial ovum is now situated. This cavity is of course the first stage of the Graafian follicle, and the single layer of epithelium lining it, or covering the ovum, is the commencement of the cellular lining which afterwards becomes largely developed in the tunica granulosa.

Enclosure in Graafian Follicles.—While this is going on, and at a time which varies considerably in different animals, but is comparatively early in the human ovary, the ovarian stroma has advanced rapidly so as to enclose first the groups of primordial ova in the tubes and nests, and then the individual ova, with their still very imperfect epithelium; and the wall of the Graafian follicle comes to be formed by a layer of condensed stroma surrounding each space containing an ovum. In many animals the ova remain in this condition for a long time, occupying the germinal stratum at a short distance from the surface of the ovary, as may be most distinctly seen in the ovary of the kitten (see figs. 612 and 613, p. 715), and this stratum of primordial ova is even recognisable in some animals of adult age. In the human ovary the tubes and nests are more equally diffused through the substance of the ovary than in most animals, and, indeed, so much so, and in such numbers, that in the human embryo of from four months up to the period of birth the ovary seems to be an entire mass of primordial ova, with only a slight admixture of the stroma and other tissues; and it is calculated that in the earlier part of this stage the ovaries of the human fœtus may contain not fewer than 70,000 cells having all the characters of primordial ova.

Wall of the Follicle.—When, however, a certain number of the ova begin to be further developed, they retire from the surface into the deeper stroma of the ovary, the most advanced being generally situated at the greatest depth, but at some distance from the hilus. (See fig. 615, p. 719.) When this takes place, we observe, along with the enlargement of the parts both of the ovum and follicle, other changes. The ovarian stroma, or fibro-nuclear tissue, forms layers round the follicle, being firmer and more fibrous externally, and looser with somewhat rounder cells next the cavity, and into the inner of these layers a rich network of blood-vessels soon penetrates. In the more advanced stage, also, we can distinguish a fine homogeneous limiting or basement membrane within.

Granular-cell Lining.—In the interior, and surrounding the ovum, the epithelial cells, which were at first flat and sparse, have now been multiplied, and have assumed the prismatic shape, so as to give a complete and compact lining to the follicle. In subsequent stages the cells of this epithelial lining rapidly increase, so as to form at first several, and then more numerous layers; and when the follicle has attained some size a fissure occurs in these granular cell layers on one side, which leaves the ovum surrounded by a set of the cells which are in contact with the wall of the follicle, while the interval gradually increasing between the ovum so enclosed and the opposite wall of the follicle, there is thus produced the follicular cavity. In the much greater expansion of the follicle which accompanies full maturation of the ovum, it is mainly by the accumulation of fluid in this cavity that the enlargement is produced.

In the ovum itself changes also take place, first of all by some increase of size, which however remains greatly inferior to that of the follicle, so that while the follicle may attain the diameter of from $\frac{1}{10}$ to $\frac{1}{5}$ of an inch, the ovum rarely goes beyond $\frac{1}{200}$ or $\frac{1}{150}$. The reticular structure of the protoplasm in the germinal vesicle becomes more distinct, the macula well defined, the yolk-protoplasm proportionally increased in size and exhibiting yolk corpuscles, and a zona pellucida, or external membrane, gradually makes its appearance externally, being probably due to a condensation of the outer part of the yolk-protoplasm.

The primordial ovum, when first formed, has a diameter of about $\frac{1}{1200}$ to $\frac{1}{1500}$", and its germinal vesicle, or nucleus, which is then proportionally large, may be about $\frac{1}{2500}$ of an inch in diameter. When the granular epithelium has become cylindrical, and the single ovum enclosed in a simple Graafian follicle begins to sink more deeply into the ovarian substance, its diameter is nearly doubled, while the Graafian follicle is not larger than sufficient to contain it and its epithelial covering. As the ova approach maturity the Graafian follicle expands rapidly, both by an increase of its fluid and of the granular cells, while the ovum remains of comparatively small size.

2. **The Genital Passages.**—The existence at first of two sets of tubes between the internal productive organs and the external parts has already been adverted to as a feature common to both sexes. The female organs contrast with those of the male in the passages of the first being formed by the large development of one of these sets of tubes, viz., the Müllerian ducts, and in the abortive disappearance of the greater part of the other or Wolffian ducts; while in the male the ducts of Müller suffer in a great measure the abortive retrogression, and the seminal conducting tubes are produced from canals formed out of special parts of the Wolffian body and the whole of the Wolffian duct. But as in all embryoes of whatever sex both sets of tubes are originally present, while a different one of the primary tubes becomes developed into the respective permanent conducting passages, vestiges of the other primary tubes, as already stated, are always present in various degrees in both sexes.

The Female Passages.—In the female, the vagina, uterus, and

Fig. 810.

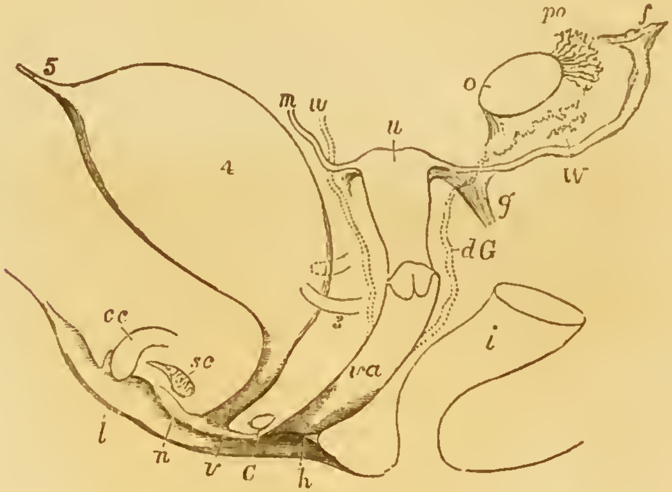


Fig. 810.—Diagram of the female type of sexual organs.

This and figure 813 represent diagrammatically a state of the parts not actually visible at one time; but they are intended to illustrate the general type in the two sexes, and more particularly the relation of the two conducting tubes to the development of one as the natural passage in either sex, and to the usual occurrence of vestiges of the other tube, as well as to the persistence of the whole or parts of both tubes in occasional instances of hermaphroditic nature.

3, the ureter joining the urinary bladder; 4, urinary bladder; 5, urachus; *o*, the left ovary nearly in the place of its original formation; *po*, parovarium, epoophoron of Waldeyer; W, scattered remains of Wolffian tubes near it, paroophoron of Waldeyer; *d* G, remains of the left Wolffian duct, such as give rise to the duct of Gaertner, represented by dotted lines; that of the right side cut short is marked *w*; *f*, the abdominal opening of the left Fallopian tube; *u*, the upper part of the body of the uterus, still presenting a slight appearance of division into cornua; the Fallopian tube of the right side cut short is marked *m*; *g*, round ligament, corresponding to gubernaculum; *i*, lower part of the intestine; *va*, vagina; *h*, situation of the hymen; C, gland of Bartholin (Cowper's gland), and immediately above it the urethra; *cc*, corpus cavernosum clitoridis; *sc*, vascular bulb or corpus spongiosum; *n*, nympha; *l*, labium; *v*, vulva.

Fallopian tubes, are formed out of the Müllerian ducts. That portion of the ducts in which they become fused together is developed into the vagina, the cervix, and part of the body of the uterus. The next following part of the Müllerian duct, constitutes in animals with horned uteri, the cornu of the uterus; but in the human subject it remains comparatively short, entering into the formation of the upper part of the organ. The remaining upper portion of the Müllerian duct constitutes the Fallopian tube—becoming at first open and subsequently fringed at a short distance from its upper extremity.

Fig. 811.

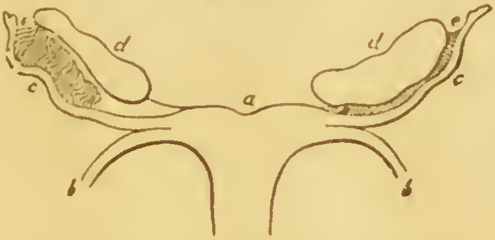


Fig. 811.—FEMALE GENITAL ORGANS OF THE HUMAN EMBRYO OF THREE MONTHS WITH THE REMAINS OF THE WOLFFIAN BODIES (after J. Müller).

a, The body of the uterus notched above: *b*, the round ligament; *c*, the Fallopian tubes; *d*, the ovaries; *e*, remains of the Wolffian bodies.

Fig. 812.

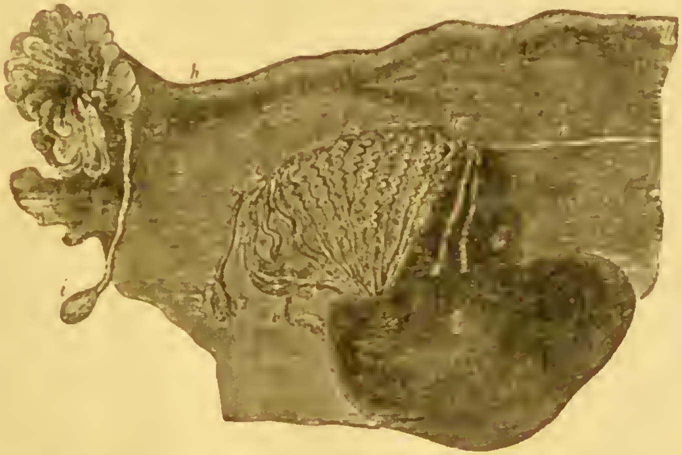


Fig. 812.—ADULT OVARY, PAROVARIUM AND FALLOPIAN TUBE (from Farre, after Kobelt).

a, *a*, Epoophoron (parovarium) formed from the upper part of the Wolffian body; *b*, remains of the uppermost tubes sometimes forming hydatids; *c*, middle set of tubes; *d*, some lower atrophied tubes; *e*, atrophied remains of the Wolffian duct; *f*, the terminal bulb or hydatid; *h*, the Fallopian tube, originally the duct of Müller; *i*, hydatid attached to the extremity; *l*, the ovary.

The additional or accessory fimbriæ and openings referred to by Henle in his Handbuch, vol. ii., p. 470, may admit of explanation on the supposition of the duct of Müller having remained open at these places.

In the human embryo of the third month the uterus is two-horned, and it is by a subsequent median fusion and consolidation that the triangular body of the entire organ is produced. The cornua uteri, therefore, of the human uterus correspond with the separate cornua of the divided uterus in animals, and this explains the occasional malformation consisting in the greater or less division of the uterine cavity and vagina into two passages. There is no distinction in the human fœtus in the third and fourth month between the vagina and uterus. In the fifth and sixth months the os uteri begins to be formed, and the neck is subsequently gradually distinguished. Thickening succeeds in the walls of the uterine portion; but this takes place first in the cervix, which up to the time of birth is much larger and thicker than the body of the uterus (Kölliker).

In the meantime the Wolffian bodies undergo a partial atrophy, and their ducts become more or less obliterated and abortive in different parts. The most constant vestige of the Wolffian bodies in the female is the now well-known body of Rosenmüller (No. 277) or Parovarium of Kobelt (No. 285) which has already been described at p. 720 of this volume, the *epoophoron* of Waldeyer, and which, being produced out of the same elements as the epididymis of the male, presents a remarkable resemblance to that body. The canal uniting the radiating tubes (coni vasculosi) of this organ is also usually persistent, but ceases at a short distance below. In the sow and several ruminants, however, and in some Simiæ, the subdivided upper tubular part or epoophoron has disappeared, and the main tube (middle part of the Wolffian duct) remains as the *duct of Gaertner*, a strong, slightly undulated tube, which is traceable, first free in the broad ligament of the uterus, and lower down becoming incorporated with the wall of the uterus and vagina, upon which last it is lost.

The Male Passages.—The conversion of the Wolffian duct into the vas deferens of the testicle was first demonstrated in animals by Rathke (No. 278, Part 4), in correction of the views of J. Müller (No. 279), and was further proved and illustrated by H. Meckel (No. 284) and Bidder (No. 282). Kölliker showed that a similar process occurs in the human embryo, and that a communication established between the seminal tubes

Fig. 813.

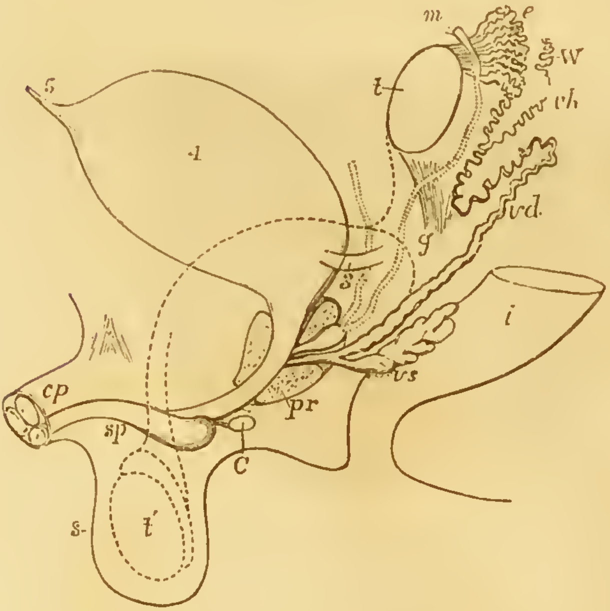


Fig. 813.—DIAGRAM OF THE MALE TYPE OF SEXUAL ORGANS.

Compare with fig. 810 3, ureter; 4, urinary bladder; 5, urachus; *t*, testicle in the place of its original formation; *e*, caput epididymis; *vd*, vas deferens; W, scattered remains of the Wolffian body, constituting the organ of Giraldès, or the paradidymis of Waldeyer; *v h*, vas aberrans; *m*, Müllerian duct, the upper part of which remains as the hydatid of Morgagni, the lower part, represented by a dotted line descending to the prostatic vesicle, constitutes the occasionally existing cornu and tube of the uterus masculinus; *g*, the gubernaculum; *vs*, the vesicula seminalis; *p r*, the prostate gland; C, Cowper's gland of one side; *c p*, corpora cavernosa penis cut short; *s p*, corpus spongiosum urethræ; *s*, scrotum; *t'*, together with the dotted lines above, indicates the direction in which the testicle and epididymis change place in their descent from the abdomen into the scrotum.

of the testicle (rete testis) and some of the upper tubes of the Wolffian body gives rise to the epididymis.

In the male, the Müllerian ducts are destined to undergo little development and are of no physiological importance, while the ducts of the Wolffian bodies, and probably also some part of their glandular substance, form the principal part of the excretory apparatus of the testicle. The united portion of the Müllerian ducts remains as the vesicula prostatica, which accordingly not only corresponds with the uterus, as was shown by Weber (No. 283), but likewise, as pointed out by Leuckart (No. 288), contains as much of the vagina as is represented in the male. In some animals the vesicula prostatica is prolonged into cornua and tubes; but in the human subject the whole of the ununited parts of the Müllerian ducts disappear, excepting, as suggested by Kobelt, their upper extremities, which seem to be the source of the hydatid of Morgagni found between the body of the testicle and upper globe of the epididymis. The excretory duct of the Wolffian body, from the base of that body to its orifice, is converted into vas deferens and ejaculatory duct, the vesicula seminalis being formed as a diverticulum from its lower part (Waldeyer).

With respect to the formation of the epididymis, it appears certain that the larger convoluted seminal tube, which forms the main part and globus minor of that body, arises by a change or adaptation of that part of the Wolffian duct which runs along the outer side of the organ. The vas aberrans or vasa aberrantia of Haller appear to be the remains also, in a more highly convoluted form, of one or more of the tubes of the Wolffian body still adhering to the excretory duct of the organ, and their communication with the main tube of the epididymis receives an explanation from that circumstance. As to the coni vasculosi in the upper part of the epididymis, it has been customary to regard them as produced by a transformation of some of the tubes in the upper part of the Wolffian body, according to the views most fully given by Kobelt; but, from more recent observations, Banks has described the origin of the coni vasculosi as more probably due to a process of development occurring in a new structure or mass of blastema which had been previously observed by Cleland, and which is formed in connection with the upper part of the Wolffian body, and close to the Müllerian duct; while Kölliker holds that sufficient evidence has not yet been adduced in favour of this view.

The coni vasculosi, becoming convoluted, are connected with the body of the testicle by means of a short straight cord, which is afterwards subdivided into the vasa efferentia. The peritoneal elevation descending from the testis towards the lower extremity of the Wolffian body, is the upper part of the plica gubernatrix, and becomes shortened as the testicle descends to meet the lower end of the epididymis; the peritoneal elevation which passes down into the scrotum, and is continuous with the first, is the more important part of the plica gubernatrix, connected with the gubernaculum testis. The spermatic artery is originally a branch of one of those which go to the Wolffian body, and

Fig. 814.

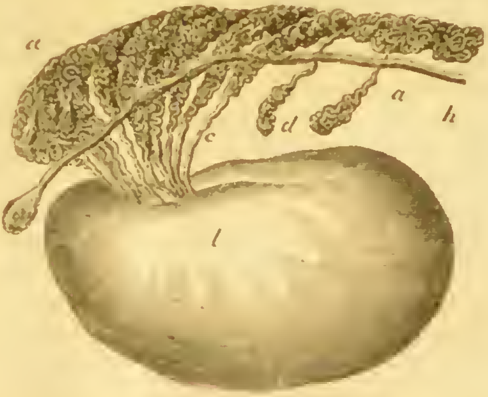


Fig. 814.—View from before of the adult testis and epididymis (from Farre, after Kobelt).

a, *a*, convoluted tubes in the head of the epididymis developed from the upper part of the Wolffian body; *b* and *f*, hydatids in the head of the epididymis; *c*, coni vasculosi; *d*, vasa aberrantia; *h*, remains of the duct of Müller with *i*, the hydatid of Morgagni at its upper end; *l*, body of the testis.

ascend from the surface of the Wolffian body to the upper part of the testis, along the ligaments connecting them; but, as the testis descends, the artery lies entirely above it, the secreting substance of the Wolffian body remaining adherent to it; and hence it is that the organ of Giraldès, which consists of persistent Wolffian tubules, is found in a position superior to the epididymis. (Banks, No. 290).

The Descent of the Testicles.—The testicles, which are originally situated in the abdominal cavity, pass down into the scrotum before birth. The testicle enters the internal inguinal ring in the seventh month of fœtal life: by the end of the eighth month it has usually descended into the scrotum, and, a short time before birth, the narrow neck of the peritoneal pouch, by which it previously communicated with the general peritoneal cavity, generally becomes closed, and the process of peritoneum, now entirely shut off from the abdominal cavity, remains as a separate serous sac. The peritoneal pouch, or processus vaginalis, which passes down into the scrotum, precedes the testis by some time in its descent, and into its posterior part there projects a considerable columnar elevation. There is likewise a fibrous structure attached inferiorly to the lower part of the scrotum, and surrounding the peritoneal pouch above, which may be distinguished as the *gubernacular cord*, both this and the plica gubernatrix being included in the general term *gubernaculum testis* (J. Hunter, No. 276). The gubernacular cord consists of fibres which pass downwards from the sub-peritoneal fascia, others which pass upwards from the superficial fascia and integument, and others again which pass both upwards and downwards from the internal oblique muscle and the aponeurosis of the external oblique; it exhibits, therefore, a fusion of the layers of the abdominal wall. Superiorly, it surrounds the processus vaginalis, without penetrating the plica gubernatrix; and the processus vaginalis, as it grows, pushes its way down through the gubernacular cord and disperses its fibres. By the time that the testis enters the internal abdominal ring, the processus vaginalis has reached a considerable way into the scrotum; and, as the testis follows, the plica gubernatrix becomes shorter, till it at last disappears; but it cannot be said that the shortening of the plica is the cause of the descent of the testicle, and much less that (as has been held by some) the muscular fibres of the gubernacular cord are the agents which effect this change of position. The arched fibres of the cremaster muscle make their appearance on the surface of the processus vaginalis as it descends, while its other fibres are those which descend in the gubernacular cord. (See Cleland, No. 289).

3. **The External Organs.**—In the human embryo, as before stated with respect to animals, the external organs are up to a certain time entirely of the same form in both sexes; and the several organs which afterwards distinguish the male and female externally take their origin respectively from common masses of blastema of precisely similar structure and connections. The common cloaca exists till after the fifth week, and the genital eminence from which the clitoris or penis is formed makes its appearance in the course of the fifth and sixth weeks in front of and within the common orifice. In the course of the seventh and eighth weeks the common orifice is seen to become divided into two parts, viz., the longer slit of the genito-urinary aperture anteriorly, and the narrower and more rounded anal aperture posteriorly: but the exact manner in which the separation of these two apertures takes place has not yet been accurately traced. This process is intimately connected with the formation of the urogenital cord as an independent structure, and is probably mainly effected by the advance from the sides and posteriorly of septal bands which divide the cloaca into a dorsal or anal and a ventral or urogenital part. Somewhat later, or in the ninth and tenth weeks, a transverse integumental band completes the division between the anal and the urogenital orifices, which band forms the whole of the

so-called perineum of the female, and the part of the perineal integument in the male which is situated behind the scrotum; the raphé being most obvious in the male sex.

Two apertures are now seen to occupy the perineal region. Of these the dorsal one or anus is of a rounded form and small size, and is surrounded by a small circular integumental ridge; the anterior or urogenital aperture forms a narrow vertical slit wider behind than before, and running forward into the rudiment of the penis, or clitoris.

The well marked eminence in the integument which forms this rudiment, at first indifferent in the two sexes, is surrounded by a deep circular fold of the integument which encompasses its base, and which in the separate condition is the foundation of the mons veneris and labia majora in the female, and when united by median fusion, of the scrotum in the male. The lips of the urogenital furrow, which in the female are converted into the nymphæ, and in the male unite as integument below the penis, are both at first precisely the same in all embryoes. In the open condition, which continues until the eleventh or twelfth week, the parts appear alike in both sexes, and resemble very much the more advanced female organs. The rudiments of *Bartholin's* or *Cowper's glands* are, it is said, seen at an early period, near the root of the rudimentary clitoris or penis, on each side of the genito-urinary passage.

Fig. 815.

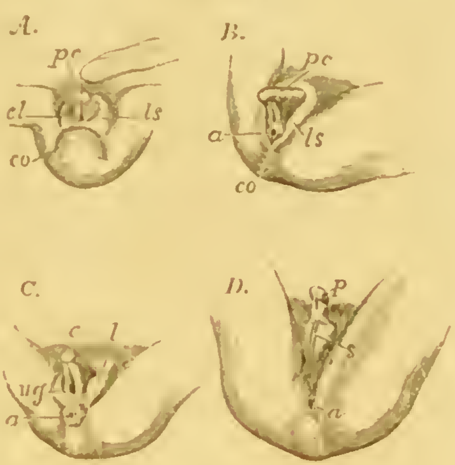


Fig. 815.—DEVELOPMENT OF THE EXTERNAL SEXUAL ORGANS IN THE MALE AND FEMALE FROM THE INDIFFERENT TYPE (from Ecker).

A, the external sexual organs in an embryo of about nine weeks, in which external sexual distinction is not yet established, and the cloaca still exists; B, the same in an embryo somewhat more advanced, and in which, without marked sexual distinction, the anus is now separated from the uro-genital aperture; C, the same in an embryo of about ten weeks, showing the female type; D, the same in a male embryo somewhat more advanced. Throughout the figures the following indications are employed; *pc*, common blastema of penis or clitoris; to the right of these letters in A, the umbilical cord; *p*, penis; *c*, clitoris; *cl*, cloaca; *ug*, urogenital opening; *a*, anus; *ls*, cutaneous elevation which becomes labium or scrotum; *l*, labium; *s*, scrotum; *co*, caudal or coccygeal elevation.

In the female, the two external folds of integument enlarge, so as to cover the clitoris as the *labia majora*. The clitoris itself remains relatively smaller, and the groove on its under surface becomes less and less marked, owing to the opening out, and subsequent extension backwards, of its margins to form the *nymphæ*. The vascular bulbs, sunk more deeply in the tissues, remain distinct and separate, except at one point where they run together in the glans clitoridis. The *hymen* begins to appear about the fifth month as a fold of the lining membrane at the opening of the genital passage into the urogenital sinus. Within the vestibule, which is the shortened but widened remains of the urogenital sinus, the urethral orifice is seen, the urethra itself undergoing considerable elongation.

In the male, on the contrary, the *penis* continues to enlarge, and the margins of the groove along its under surface gradually unite from the primitive urethral orifice behind, as far forwards as the glans, so as to complete the long canal of the male *urethra*, which is therefore a prolongation of the urogenital sinus. This is accomplished about the fifteenth week. When this union remains incomplete, the abnormal condition named *hypospadias* is produced. In the meantime the *prepuce* is formed, and, moreover, the lateral cutaneous folds also unite from behind forwards, along the middle line or *raphé*, and thus complete the *scrotum*, into which the testicles descend in the course of the eighth month of fœtal life, as before described.

The corpora cavernosa, which are at first separate, become united in their distal portions in both sexes; but the corpus spongiosum urethræ which is also originally divided in all embryoes, and in the female remains so in the greater part of its extent, becomes enlarged in the male in the glans penis, and its two parts united mesially both above and below the urethra, so as to enclose the whole of that tube from the bulb forwards to the glans.

TYPE OF DEVELOPMENT AND ABNORMAL FORMS.

The type of development in the several parts of the genital organs may be stated to differ in the two sexes as follows, viz. :—

1st. In the external organs it is single and homological. 2nd. In the middle organs or passages it is double and heterological. 3rd. In the productive organs it is single and homological as regards the productive elements, but with some difference of the sources from which the containing capsules of the ovary or tubes of the testicle are respectively derived. This is illustrated by the table placed on p. 911.

Accordingly the congenital malformations of the reproductive organs admit of being distributed under the following divisions :—

1st. Abnormal forms attributable to variations in the development of one or more of the external organs in either sex, producing an approach to the form of the other sex.

2nd. Forms referrible to variations in the development of the Wolffian or Müllerian ducts, so as to lead to the greater or less predominance of sexual characters in a part or the whole of either of these passages inconsistent with those prevailing in other parts of the system, or to the coexistence of both sets of passages in whole or in part.

3rd. Extremely rare forms referrible to the possible coexistence of the productive parts of testicles and ovaries in the same individual, which may be combined with more or less of the foregoing kinds of malformation.

As an example of this last form reference may be made to the case described by Heppner, of St. Petersburg, in which microscopic examination showed the presence of small ova in Graafian follicles in the one pair of bodies and of seminiferous tubes and spermatic cells in the other. (No. 334.)

Upon the subject of Hermaphroditism consult Simpson (No. 333).

MALFORMATIONS IN GENERAL.

In the preceding pages we have frequently had occasion to refer to the relation subsisting between the natural development of organs and their abnormal conditions or malformations. There can be no doubt that a considerable number of congenital malformations, more especially those of the nature of *defect*, whether by non-formation or deficient growth of the parts in which they occur, or by want of union between those which naturally fuse together, as well as many abnormal conditions depending on misplacement and altered form and structure, may be attributed in some measure to an arrest of the process of development, or a variation in some part of it, in the earlier stages of embryonic life, and may therefore receive much illustration from the study of the natural process of formation. But comparatively little light has yet been thrown by this study upon the origin of that large class of malformations in which there is *redundance* of parts, either by more or less complete duplicity of the whole body or by an increase in the number of individual parts. At the same time it is obvious that, since in these as in all other malformations the histological and morphological processes of development do not differ essentially in their nature from the natural ones, but are only modifications and variations of them, the knowledge of the true nature of the abnormal structures must follow closely upon our acquaintance with the natural processes of development.

Upon this extensive subject, which does not come within the scope of this work, the reader is referred to the masterly Essay of Bischoff (No. 312), and other treatises quoted in the Bibliography at p. 918.

Tabular scheme of the CORRESPONDING PARTS of the genito-urinary organs in the two sexes, and of their relation to their EMBRYONAL ELEMENTS :—

ADULT FEMALE.	EMBRYONAL.	ADULT MALE.
	I.—GERMINAL RIDGE.	
Ova.	1. Germ-epithelium	**Spermatic cells.**
Stroma of the ovary and Graafian follicles.	2. Deeper blastema with Wolffian stroma.	**Seminal tubes.**
	II.—MULLERIAN DUCTS.	
	(Ducts of Pronephros.)	
Fimbriated Fallopian opening and occasional hydatids.	1. Anterior extremity	**Hydatid** of **Morgagni.**
Fallopian tubes	2. Middle part	Tubes extending from the uterus masculinus.
Vagina and uterus	3. Posterior single part	**Uterus masculinus** or **prostatic vesicle.**
	III.—WOLFFIAN BODIES (MESONEPHROS).	
Smaller tubes of **epoophoron,** (Organ of Rosenmuller (Parovarium.)	1. Anterior segmental tubes.	**Vasa efferentia** and coni vasculosi of the epididymis.
Paroophoron (Wald.)	2. Posterior segmental tubes...	**Paradidymis** (Wald.), organ of Giraldès, and vasa aberrantia.
Round ligament of the uterus.	3. Ligament of the Wolffian body.	**Gubernaculum testis.**
	IV.—WOLFFIAN DUCTS.	
Main Tube of the Epoophoron	1. Anterior and middle parts	Convoluted tube of the **epididymis.**
Ducts of Gaertner, of some animals.	2. Posterior part	**Vas deferens** and vesiculæ seminales.
	V.—METANEPHROS.	
Kidney	1. Tubular portion	**Kidney.**
Ureter	2. Duct	**Ureter.**
	VI.—GENITAL CORD AND SINUS UROGENITALIS.	
Tissue uniting female urethra and vagina.	1. Substance surrounding genital cord.	**Prostate gland.**
Female urethra	2. Urinary pedicle.	**Prostatic portion of urethra** above **vasa deferentia.**
Ostium vaginæ. Hymen	3. Confluence of genital with urinary parts.	**Verumontanum.**
Vestibule	4. Lower part	Lower **prostatic** and **membranous part of urethra.**
Bartholin's Glands	5. Common blastema	**Cowper's Glands.**
	VII.—EXTERNAL ORGANS.	
	1.—*Vascular parts.*	
Crura and corpus clitoridis	*a.* Corpora cavernosa	**Crura** and **corpus penis.**
Glans clitoridis and **vascular-bulbs**	*b.* Corpora spongiosa	**Glans penis** and **spongy body.**
	2.—*Integumental parts.*	
Preputium clitoridis	*a.* On genital eminence	**Preputium penis.**
Folds of **nymphæ**	*b.* Lips of genital ridges	**Raphé** below penis.
Mons veneris and **labia majora**	*c.* Cutaneous wall	**Pubic eminence** and **scrotum.**
Perineum of female, with raphe..	*d.* Transverse ano-genital band	**Perineum** of male behind scrotum, with raphé.

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